HAER No. WA-127

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D-Reactor Complex
100-D Area
Hanford Site
Richland Vicinity
Benton County
Washington

PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Western Region
Department of the Interior
San Francisco, California 94107

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HISTORIC AMERICAN ENGINEERING RECORD

D-REACTOR COMPLEX

HAER NO. WA-127

Location: 100-D Area, Hanford Site, 35 miles north of Richland, Benton County, Washington.

USGS Coyote Rapids Quadrangle, Washington, 7.5 Minute Series Township 14 North, Range 26 East, Sections 22 & 23 of Willamette Meridian.

UTM Coordinates: Zone 11, Easting 306010-306080, Northing 5173900-5174050.

Date(s) of Construction: 1944, 1957, 1970

Engineer:

Builder: E. I. DuPont De Nemours & Company, Inc., and General Electric Company

Present Owner: U. S. Department of Energy, Washington, D. C.

Present Use: Buildings abandoned; in process of deactivation for removal of hazardous substances.

Significance: 185-D, 189-D and 190-D, buildings in what is commonly known as the 190-D complex, were completed in December, 1944 in conjunction with the start-up of D-Reactor. (190-DA, 195-D, and 1724-DA, the other facilities in the 190-D complex, were added later.) D-Reactor was one of three production reactors constructed at Hanford during the Manhattan Project and the Second World War. Two buildings in the 190-D complex, 185 and 189-D, have been determined eligible for the National Register of Historic Places due to their significant role in nuclear reactor technology in the D-Reactor complex. While 190-D, 190-DA, 195-D and 1724-DA individually are not eligible for the Register, collectively they have significance due to their structural proximity and common functional elements with 185/189-D.

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Date: September 1995

Hanford Site - Mission

In 1943 the Manhattan Engineer District (MED) of the U. S. Army Corps of Engineers chose Hanford, Washington, as the site of the world's first plutonium production facilities. The development of atomic power on the Hanford Site represents a significant national event that profoundly shaped and defined military strategies and wartime events during the 1940's and plutonium production policies in the years following. The efforts in scientific research and development during the Manhattan Project (1943-1946) through the Cold War period influenced national developments and policies in energy production, medical technologies and plutonium production for national defense.

The lessening of Cold War tensions in the late 1980's accelerated the change of mission at Hanford to one of environmental remediation, restoration and waste management. N Reactor, the last plutonium production reactor in operation, assumed a cold standdown status in February 1988. Permanent shutdown of the facility was ordered in October 1991. In 1989 the Hanford Federal Facility Agreement and Consent Order (the Tri-Party Agreement) was signed. The three signatories, State of Washington, the U. S. Environmental Protection Agency, and the U. S. Department of Energy, agreed to an environmental clean-up of the Hanford Site.

100 Areas: D-Reactor and the 190-D complex

The plutonium production process at Hanford involved three essential steps: uranium fuel elements were fabricated and jacketed in the 300 Area, irradiated in the 100 Areas, and chemically dissolved and separated into plutonium, unconverted uranium and various fission byproducts in the 200 Areas.

The production reactors, and their ancillary and support facilities, were constructed along the south and west banks of the Columbia River in the 100 Areas of the Hanford Site. While at least one reactor was eventually built within each 100 Area, only three reactors, B, D, and F, were built at Hanford during World War II. D-Reactor was the second to begin operating; starting up on December 17, 1944.

The production reactors functioned to irradiate uranium fuel elements, the second step in the plutonium production process. Most of the support buildings operated to supply, treat, store and carry away the reactor cooling water, to supply gas, electricity, fresh fuel and materials to the reactors, to test reactor samples, and supply protection, training services, maintenance services and other support functions to reactor operations.

The 190-D complex, a support facility to D-Reactor, was completed by the DuPont Corporation just prior to the start-up of D-Reactor in December,1944. The complex consisted of the 189-D Refrigeration Building, the185-D Deaeration

Building and the 190-D Tank Room and Process Pumphouse. 190-DA (Annex), 195-D, and 1724-DA were added later.

185-D, 189-D and 190-D were constructed to be part of the "influent water cooling system for D-Reactor. Cooling water first was pumped from the Columbia River at the 181-D River Pump House, purified and treated in the 182-D Reservoir and Pump House and in the 183-D Filter Building, deaerated in the 185-D Plant, and then cooled in the 189-D refrigeration building. Water then flowed into the 190-D Process Pump House, and was delivered to the front risers of the reactor building itself" (Gerber 1994: 1).

Historical Background

189-D AND 185-D BUILDINGS

ORIGINAL CONSTRUCTION AND USAGE

The 189-D Refrigeration Building and the 185-D Deaeration Building were constructed at the Hanford Engineer Works (HEW - WW II name for the Hanford Site) by the DuPont Corporation during 1943-44. They were completed in late 1944 just prior to the start-up of D-Reactor on December 17, 1944. The 189-D facility contained six industrial refrigeration units, six evaporative coolers, seven pumps, as well as various lifts, hoists and freon tanks. It contained no personnel service facilities such as rest rooms or lunch rooms. The 185-D Building was situated east and adjacent of the 189-D Building. It contained ten, four-stage, rubber-lined deaeration units ("towers") mounted vertically on steel structures, 20 acid dilution tank pumps, 18 other pumps, 16 chemical storage tanks, a proportioner feed tank, and a one/half ton transfer monorail and hoist. Both buildings were constructed to be part of the influent water cooling system for D-Reactor. The original plan called for cooling water to be pumped from the Columbia River at the 181-D River Pump House, purified and treated in the 182-D Reservoir and Pump House and in the 183-D Filter Building, demineralized in the 186-D Demineralization Plant, deaerated in the 185-D Deaeration Plant, and then cooled in the 189-D Refrigeration Building. Water then would flow into the 190-D Process Pump House, and be delivered to the front risers of the reactor building itself.[1]

The original purpose of the 189-D structure was to deliver chilled water to the central process tubes of D-Reactor (those that were expected to become the

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1 DuPont, HAN-10970, Book III, pp. 736-737, 747-48; and Hanford Engineer Works, OUT-1462, pp. 18, 88; and DuPont, HAN-73214, Book 14, pp. 136-137; and Reinker, HW-22110.

Note: The most authentic description of the physical characteristics and functions of the 189-D and 185-D Buildings can be found in DuPont, HAN-10970, Book III, pp. 736-737, 747-48; and in DuPont, HAN-73214, Book 14, pp. 136-137; and in Gerber, WHC-MR-0425, pp. 8-9.

hottest due to the high neutron flux in the center of the reactor). It was thought that such refrigeration would be needed during the summer months (when river temperatures were higher), in order to assure that the overall bulk outlet operating limit of 65 degrees C for effluent water (after passage through the operating reactor) would not be exceeded. In practice, refrigeration was effected for half of the 30,000 gpm (gallons per minute) stream of D-Reactor process water. The 15,000 gpm flow that was to be refrigerated was valved through the 189-D Building, and then directed to the two center process water storage tanks ("clearwells") of the 190-D Building. Refrigeration was begun in the 189-D Building on April 20, 1945, and discontinued on October 8. It was resumed on May 6, 1946, but the date that it was discontinued is unknown.[2]

The original purpose of the 185-D facility was to purify reactor process water by removing dissolved gasses, especially oxygen. Such "degassification" of the coolant water was obtained by passing it through towers in which a vacuum was maintained via steam jets. Equipment to feed acids, sodium dichromate and sodium silicate was provided at the towers for corrosion control.[3]

However, at the same time that the 185-D Building was being constructed, extensive water treatment and corrosion studies were underway at HEW. A special corrosion study "laboratory" was established in the Hanford Construction Camp in September 1943. Known as the CMX facility (Building 145), the laboratory was located on the bank of the Columbia River about one-quarter mile north of the Chicago, Milwaukee and St. Paul Rail Depot in the pre-Site town of Hanford. The CMX assignment was to develop, via experiments with actual river water, the process treatment standards for reactor influent water. By January 1944, CMX experiments had found film formation on simulated reactor process tubes to be a serious problem, but they also had found no difference with or without the use of deaerated water. According to DuPont: "Therefore, in order to eliminate one variable and obtain a more rapid solution to the film problem...all runs using deaerated or demineralized process water were stopped." In late October 1944, with the HEW process water standards in place, the CMX operation was shut down and the huge dearation equipment installed in the 185-D Building (as well as the demineralization equipment in the 186-D Building) was never used. Both sodium silicate and sodium dichromate were fed into the reactor coolant at the 183 filtration plants.[4]

EARLY GAINS IN KNOWLEDGE END ORIGINAL 189-D BUILDING MISSION

Over the years between 1946 and 1951, a great number of changes occurred in reactor operations at the Hanford Works (HW - the Atomic Energy Commission's name for the Hanford Site from 1947-1973). One early effort was

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[2] DuPont, HAN-73214, Book 11, pp. 79, 111, 137; and HW-10475-B, pp. 1110.

[3] Hanford Engineer Works, OUT-1462, p. 18; and

[4] DuPont, HAN-73214, Book 14, pp. 117-126; and Hanford Engineer Works, OUT-1462, pp. 78-79; and Kidder, HW-7-4444; and Conley, HW-15943; and Conley, HW-20342; and Fryar, HW-23742, pp. 25-26.

directed at "flattening" the pronounced cosine curve that existed in the neutron flux (front to rear, and side to side) within each "pile" (an early term for a reactor). This curve was produced when the earliest reactor operators distributed "poisons" (neutron absorbing materials) in a uniform pattern throughout the reactor lattice. Such a distribution was undesirable because it meant that only the uranium fuel elements in the central process tubes of the reactor attained maximum or optimum irradiation, while the uranium in the "fringe" (non-centrally located) tubes received sub-optimal irradiation. Additionally, the central tubes became the hottest, while the rest of the reactor remained cooler. These temperature gradients caused graphite expansion in the centers of the reactor, a situation that worried Hanford scientists because it contributed to deformation of the graphite stack. Shortly after the end of WW II, experiments were undertaken that varied the poison patterns and achieved a more "flat" curve or uniform neutron flux. This new technique and knowledge led to the discontinuation of refrigeration of the cooling water at HW.[5]

CORROSION STUDIES REMAIN IMPORTANT AT EARLY HANFORD

Corrosion of the aluminum process tubes and the aluminum-silicon jacketing ("cladding") of the uranium fuel elements in the Hanford reactors remained a problem despite the best efforts of the CMX to develop adequate water treatment methods. Process tube films, composed of various metallic oxides and other corrosion products, became the object of intense study by the "Water, Corrosion and Engineering" group within the 100 Areas laboratory organization in 1945, after just a few months of reactor operations. The films decreased the ability of the process water to contact and cool the fuel elements, thus causing heat build-up within the reactors, and they allowed corrosion build-up, thus shortening the life of process tubes.[6]

POWER LEVEL INCREASES RAISE NEED FOR CORROSION INFORMATION

Shortly after WW II ended, corrosion studies heightened as Hanford scientists embarked on very preliminary tests to increase the power levels of the reactors. As power levels rose, they knew, the higher water temperatures and the increased volumes of cooling water through the process tubes would aggravate corrosion. The power level of D-Reactor was increased to 275 megawatts (MW) in December 1945, 25 MW above its design capacity.[7]

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[5] DuPont, HAN-73214, Book 15, pp. 138-141; and Milton, HW-3-6898; and Menegus, HW-7-2744; and HW-10475-B, pp. 1110-1125; and Wende, HW-7-3486; and Wende, HW-7-3834.

[6] DuPont, HAN-73214, Book 15, pp. 111-114; and Smith and Worthington, HW-3-2074; and Hanford Engineer Works, OUT-1462, p. 88.
Note: There were <u>many</u> other studies pertaining to corrosion, film formation and heat transfer at Hanford during this time period. The references shown are a tiny portion of the existing documentation.

[7] Worthington, HW-7-1936; and Simon and Smith, HW-7-1948; and Wende, HW-7-2520-DEL, pp. 25, 44; and DuPont, HAN-73214, Book 15, pp. 135-137; and Jordan,

Although there was acute interest in pursuing the experiments in increased power levels, the trials were abandoned after just one month, due to restructuring in the federal management organizations for the Hanford Site and to a change in the Site contractor in 1946. The great expansion of the production capacity and facilities of the Hanford Site that occurred during 1947-48 again delayed extensive power level tests, but basic research in corrosion and into the factors that affected heat transfer and cooling capacity within process tubes continued.[8]

By January 1946, a "flow laboratory" at F-Reactor, left in partially completed "standby condition" since WWII, was conducting tests to measure the curvature or "bowing" of process tubes and of the vertical "thimbles" (aluminum linings) in the vertical safety rod (VSR) channels of the reactor.[9] In the summer of 1947, an old flow laboratory at D-Reactor, that had stopped operations in March 1945, was being refurbished and expanded. A "hot" facility (i.e., one using radioactive substances) the 105-D Flow Laboratory was located in the riser room in the 105-D Building (the D-Reactor building itself). The new test equipment consisted of a full mock-up of a reactor process tube fed by irradiated water from the rear face of the reactor, and discharging via another special line at the discharge face. It also had a "cold side" (non-radioactive), wherein tests could be run to duplicate flow conditions and temperatures in process tubes, but without the factor of radioactivity. For these tests, process water was piped from the valve pit at the front face of 105-D.

The first experiments in the 105-D Flow Lab measured corrosion in various gasket materials that connected the Van Stone flanges (flared openings on the ends of the process tubes) with the gunbarrels (carbon-steel sleeves that supported the ends of the process tubes where they passed through the reactor shields). Other early tests measured "chattering" (up and down movement, also known as "fluttering") of fuel elements of various diameters within process tubes.[10] At the same time, pressure drop tests, and trials involving spacers (simulated fuel elements not containing uranium) of varying diameters and densities, were conducted in the 105-F Flow Laboratory.[11]

The 105-F and the 105-D Flow Laboratories continued to operate throughout 1948-51, conducting varied experiments with anodized coatings for reactor process tubes, nozzle assemblies, galvanic corrosion, and other issues related to the water cooling of the Hanford reactors. Since galvanic corrosion

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HW-7-3188; and Jordan, HW-7-3307; and Jordan, HW-7-3392; and Jordan, HW-7-3441; and Jordan, Wende and Gast, HW-7-2984, p. 16.

8 Jordan, Wende and Gast, HW-7-2984, p. 27; and Hewlett and Anderson, The New World, pp. 482-655; and Hewlett and Duncan, Atomic Shield, pp. 1-154.

9 Jordan, HW-7-3392, p. 7; and DuPont, HAN-73214, Book 14, p. 132.

10 DuPont, HAN-72314, Book 14, p. 132; and Wende, HW-7-6311; and Woods, HW-7-6254; and Woods, HEW-7178, p. 3; and Woods, HEW-7431, pp. 3-4; and Woods, HEW-7597, pp. 3-4; and Woods, HW-7827, pp. 1-3; and Woods, HW-8491, pp. 5-6.

11 Woods, HW-7-6254; and Woods, HEW-7178, pp. 8-9.

was such an important issue, small vessels (known as "cups") containing water of different Ph levels, and treated with different levels of process chemicals, were placed in the 105-D Flow Laboratory. Then, metallic coupons (short test pieces) were placed in the solution, and electric current was passed through them. These experiments eamed the 105-D Laboratory the nickname the "Flow Cup Lab". It also sometimes was known as the "Corrosion Lab". In late 1948, a heat exchanger was added to this laboratory to provide a source of heated process water for the flow cup tests, and by December 1949, a total of 353 flow cups were available for studies. In March 1949, a process tube with a lucite[12] window insert was installed in the 105-D Flow Lab in order to study fuel element fluttering within the tube.[13]

FURTHER JUMP IN POWER LEVELS AND CORROSION ISSUES OBVIATE NEED FOR NEW FACILITY

The need for a thorough understanding of corrosion issues at the Hanford Site increased dramatically in the 1950-51 period. In the spring of 1949, the long-delayed experiments in increasing the power levels of Hanford's reactors was resumed. That February, the power level at D-Reactor was raised to 275 MW for the first time since December 1945. An incremental test program ensued that brought the operating power level of B-Reactor to 340 MW by mid-1950, and H-Pile to 470 MW by December. That same year, trials were authorized for the 600 MW level, and Hanford scientists began conducting in-depth design reviews to determine the equipment changes that would be necessary for such operations.[14]

One of the most crucial aspects of safe operation at higher power levels, they realized, was to maximize and improve the coolant water delivery systems. Such maximization could not come simply from installing larger pumps in the 190 Buildings, although certainly this would have to be done. If more throughput of water simply led to accelerated corrosion and shortened reactor life, then little would have been gained by the higher power levels. They knew that they had much to learn about pressure drop, improved valves, nozzles, the connectors between the process tubes and the front crossheaders, the corrosion properties of different metals and alloys, chattering and "cocking" (misalignment) of fuel

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12 Lucite is a trademark of the DuPont Corporation, Wilmington, Delaware.

13 Woods, HW-9005, pp. 1-2. 7; and Woods, HW-9314, pp. 1, 7-8; and Woods, HW-9955, pp. 1, 3-4; and Woods, HW-10160, pp. 5-6; and Woods, HW-10548, p. 6; and Etheridge, HW-32664; and Pile Engineering, HW-11829, pp. 4-5; and Reinker and Johnson, HW-15295, pp. 2, 5; and Reinker and Johnson, HW-15715, p. 2; and Woods, HW-13007, p. 3.
Note: Additional sources exist for the 105-D and 105-F Flow Laboratories, but they are not the subject of this report.

14 Gast, P.F., HW-13022, p. 1; and Wende, HW-13184; and Greninger, HW-15620-DEL; and Lewis, HW-19068; and Plum, PWM-542, p. 1; and Alexander, HW-19955, p. 9; and Pike, Letter to LeBaron, April 1950; and Carbon and Fryar, HW-20425.

elements within the process tubes, and many other aspects of heat transfer. In December 1950, assessing barriers to higher power levels, Site scientists observed: "Pressure, flow and water quality... are the factors which determine the [power] limits based on the possibility of vapor binding, corrosion and film formation in the piles...Only rough estimates [of potential power levels] can be made until further information has been obtained."[15]

185-D and 189-D BUILDING CONVERTED TO FLOW LABORATORY

Consequently, the original equipment was removed from the 185-D and 189-D Buildings, part of their common wall was removed, and a new corrosion, heat transfer and "thermal hydraulics laboratory" was emplaced in the now-joint structure. As prime operating contractor General Electric Hanford Company explained in a "guide" to its facilities, "The 189-D Building is now considered to be a single building but is made up of what was originally 185 and 189 [D]."[16] Key developments in 1951 that facilitated the decision to build the facility included a final analysis that it would be cheaper and more feasible to pump more cooling water through the Hanford reactors than to use a smaller volume of refrigerated water. Additionally, this analysis concluded: "Recent data pointed to the possibility that corrosion may be more affected by slug [fuel element] heat generation than outlet water temperature. For this reason, some revision to outlet water temperature appears likely."[17]

Conversion and modifications within the 185/189-D facilities began in April 1951, and were completed that December. Equipment included 60 short process tube mock-ups, several sets of hydraulic heads for these tubes, a 50 kilowatt (KW) electrical induction heating coil, a weighed tube corrosion apparatus, "dummy" fuel elements (simulations of uranium fuel elements but made of various other solid metals such as aluminum, magnesium and others), a 25-ton crane capable of traversing the entire length of the 189-D Building, and stacked graphite blocks to simulate varying deflection slopes for process tube entry. A lunch and change area for employees was constructed out of part of the original electrical control room in the facility. At the same time, changes and additions were made to the 105-D Flow Laboratory, and the 105-F Flow Laboratory continued to conduct tests. In mid-1951, an expanded Pile Technology Unit, including a Heat Transfer Group, was formed within the Reactor Section of the newly re-organized Manufacturing Department of the G.E. Hanford Company. The 1703-D building was built to house the Pile Technology group, so that they could pursue their enlarged program of water studies.[18]

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15 Windsheimer, HW-20841; and Carbon and Fryar, HW-20425; and Reinker, HW-22110; and Woods, HW-19721, p. 2.

16 Hanford Atomic Products Operation, "Tour Guide, Contractor Replacement Program," p. 19.

17 Nelson, HW-21531, p. 4.

18 Botsford and Alexander, HW-20188, pp. 18-19; and Botsford and Alexander, HW-20406, p. 24; and Alexander, HW-21931, p. 5; and Alexander, HW-22346, p. 9; and

Experiments in the 185/189-D Building continued throughout the next several years, contributing to the coolant flow information that allowed repeated power level increases in the Hanford reactors. Work began in January 1952 with a calibration test in the induction heating facility, in order to determine fuel element surface temperatures as a function of power input to the coil and tube cooling water flow rate. Solid aluminum dummy elements, as well as stainless steel dummies clad in aluminum, were used in these tests. The following month, high temperature corrosion studies, using process water with varied pH levels, were underway. At the same time, knowledge about how film was formed within the process tubes became even more crucial. A slotted process tube was fabricated and emplaced for film formation and corrosion testing, and examinations of the role colloidal particles from the Columbia River in film formation were begun. Further, "weight loss" experiments were conducted in the weighed tube apparatus (weight loss data being used to determine corrosion rates), and corrosion trials of aluminum pieces coupled to graphite samples and exposed to diverse water temperatures were undertaken.[19]

A large Horizontal Control Rod Mock-Up apparatus was constructed and tested during the spring of 1952, and a portion of an C-Reactor type horizontal control rod (HCR) was brought in to undergo galvanic corrosion tests. Installation of Resistance Heating Equipment was completed in May, and testing of fuel element "specimens" fabricated in new and varied ways was begun. In a separate test assembly, an electric furnace was emplaced in the 185/189-D Building and six pieces of aluminum process tubing from DR-Reactor were brought in for metal "creep" trials. The latter test was conducted inside of a specially constructed, four-inch lead shield.[20]

185/189-D EXPERIMENTS LEAD TO HISTORIC CHANGES IN HANFORD REACTOR OPERATIONS

Other important tests conducted during the first year of thermal hydraulics operations in the 185/189-D Building included early trials of a pressurized, charge-discharge ("C-D") machine that was later perfected and used to improve the "time operated efficiency" (TOE) level of all of the Hanford reactors. Further experiments carried out during 1952 evaluated new designs in reactor process tube nozzles, "pigtails" (flexible aluminum connectors between the crossheaders

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Alexander, HW-22886, p. 20; and Alexander, HW-23153; and Fryar, HW-23742, p. 33; and Department Managers, HW-22075-DEL, pp. 29, 32; and Miller, HW-27393, p. 17; and Fryar, HW-23361.

[19] Alexander, HW-23153; and Vanderwater, HW-23251; and Carbon, HW-23669, pp. 6, 12; and Vanderwater, HW-23861; and Carbon, HW-23934; and HW-24242; and Fryar, HW-23646; and Fryar, HW-23646; and Lewis, HW-24838, p. 12.

[20] Alexander, HW-24215; and Carbon, HW-24598, p. 25; and Alexander, HW-25054, pp. 9-12; and Carbon, HW-24833; and Carbon, HW-23934, p. 4; and Carbon, HW-24242, p. 5.

Note: Metallic "creep" is a slow deformation of the metal as the result of stress, including the stress of irradiation and/or high temperature conditions.

and the nozzles on each process tube), and orifices (flow restriction devices used to maintain pressure within the process tubes). Each of the latter experiments was done using unirradiated materials, and did contribute to equipment changes later incorporated into major reactor modification projects that took place between 1956-1962.[21]

During early 1953, after a severe "pitting attack" took place within the Hanford reactor process tubes and fuel elements, knowledge concerning corrosion and water treatment chemistry became even more essential to the overall program of increasing power levels. At that time, each reactor needed approximately 200 tube replacements per year, a factor that decreased plutonium production and added to expense and "down-time" (non-operating time). Site scientists theorized that internal tube corrosion could be caused by "cavitation" (the formation of unstable vapor bubbles caused by higher water temperatures). The collapse of such bubbles ("hammering"), they suspected, caused tiny implosions that blasted at the internal tube surfaces, eventually forming holes. However, they needed empirical proof.[22]

In the 185/189-D Flow Lab, short sections of process tubes loaded with dummy fuel elements already were being exposed to various heat generation rates using the induction heating facility. Water flow rate also was diversified. Hot spots on the tubes and fuel elements were induced by placing cocked slugs at several places to reduce coolant flow. Localized boiling thus was achieved at the points of contact between the cocked elements and the tube walls. The results of these experiments demonstrated that "no excessive corrosion of the metal takes place due to the "hammering" of collapsing vapor bubbles."[23]

A related set of tests were conducted in the 185/189-D Flow Lab during 1953, to define the exact conditions of local boiling with respect to metal surface temperature and static water pressure. In this series, cans similar in aluminum composition to the process tubes used in the Hanford reactors, were machined from the inside to reduce the thickness of the walls at various places. The cans then were mounted on inserts, connected to a high direct current [d-c] generator and placed inside glass-walled process tube mock-ups. Water flow was initiated through the mock-ups, and the temperature was increased gradually via the generator. Thermocouples placed on a movable probe then measured exact temperatures as vapor boiling began at the localized hot (thinned) spots. The purpose of these experiments was to determine the probability of localized boiling

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21 Schilson, HW-23086; and Wood, HW-23955; and Carbon, HW-23865; and Johnson, HW-24602; and Alexander, HW-24834. See also: Hanford Site Project Records for Projects CG-558, CG-600, and CG-775, all entitled "Reactor Plant Modifications for Increased Production."

22 Lewis and Rohrbacher, HW-29132; and Strege, HW-32960.

23 Carbon, HW-23448, p. 15; and Carbon, HW-24598, p. 9; and Carbon, HW-25053; and Wilson, HW-28207, pp. 8-10.

on fuel element surfaces.[24] At the end of the year and the conclusion of this test series, water quality specialist N.R. Miller affirmed that the flow laboratory data were "reliable" and useful "in predicting corrosion trends experienced under in-pile conditions. This fact makes it highly desirable to continue using flow laboratory facilities to the fullest extent possible...because flow laboratory testing is much less costly and hazardous and much more flexible than is in-pile testing."[25]

WATER PROCESS SPECIFICATIONS MODIFIED

Throughout 1954, interest in data on "boiling flow" remained high at Hanford, as operators wished to push power levels and temperatures as high as was possible under safe conditions. Several tests were conducted in the 185/189-D Flow Laboratory on both full size and short process tube mock-ups. Size of tube annulus, power or heat levels, uniformity of power distribution along tube length, and header pressure (measured in pounds per square inch gauge - psig) all were varied in these experiments. The information of most interest included the amounts of pressure drop across tube length under diverse conditions, and the prediction of "safe operation close to burnout [boiling]." In order to increase heat generating capacity, additional generating equipment was installed in the building in August of that year. As a result of the above sets of 1953-1954 tests, and of 1954 trials in C-Reactor, an important change in Hanford's Process Specifications was made in early 1955. The "trip-before-boiling" limit, measured by special gauges on each reactor, was changed to the "trip-before-instability" limit. In other words, the automatic shutdown equipment on the reactors was set to activate ("trip") at higher temperatures than those previously considered safe. In effect, this change meant that nucleate boiling of the coolant within the process tubes was allowed, but that full bulk boiling was not.[26]

Another salient series of experiments carried out in the 185/189-D Flow Lab during 1954 was a cooperative program with the Pile Materials Sub-Section, the group responsible for developing and testing new alloys for use in the Hanford reactors. Assessments of tensile strength (flexibility without embrittlement, cracking or corrosion), elongation, and metallic creep measured against variables such as coolant temperature were conducted in a "minitube" apparatus in the huge building. All of this work was directed at identifying process tubes that could withstand higher power and temperature levels than the "2S" aluminum tubes used at Hanford since WWII.[27] As engineering manager A.T. Taylor stated: "Increases in production have been gained by increases in

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[24] Wilson, HW-28207, pp. 10-15.

[25] Miller, HW-27393, p. 2.

[26] McNutt, HW-34150; and Carbon and Gilbert, HW-37437.

[27] 2S aluminum was a blend of 99 percent aluminum alloyed with small amounts of zinc, manganese, copper, iron and silicon. Other alloys under consideration in this time period varied the amounts of zinc, manganese, copper, iron, and silicon, while some added chromium and magnesium.

tube water flow and outlet water temperature...It can be concluded that a stronger tube in addition to a more corrosion resistant one will be required."[28]

Still another important 1954 experiment conducted in the 185/189-D Building tested the reliability of a unique design in "resistance bulbs" (flow sensing devices) in the crossheader fittings that were used in the new K-Reactors then being built at the Hanford Works. Essential in President Eisenhower's "New Look" in armaments program, the twin KE and KW Reactors were to operate at temperatures and power levels previously not achieved in any other Hanford pile. Therefore, study and informed predictions of every aspect of their operation was considered mandatory for safety reasons. The 185/189-D tests evaluated time response in K-type process tube temperature and flow monitors under conditions that simulated a sudden blockage of flow within the tube. The test apparatus consisted of a process tube, an aluminum tube placed inside the process tube to simulate a column of fuel elements, a simulated dummy section of the effluent end, pumps, piping and valving to supply coolant, and associated control devices and monitoring instrumentation. Measurements were taken of both temperature (using a "resistance bulb") and of flow rate (using a rotating flow meter). The resulting data were plotted to demonstrate the expected time response curves for various types of blockage events. As engineer M.E. Forsman pointed out: "Attempting to obtain the data from a process tube in the reactor is not only expensive but dangerous...[Therefore] the process tube heat transfer test set-up in the 185/189-D Building was used."[29]

EXPONENTIAL PHYSICS EXPERIMENTS BROUGHT TO 189-D BUILDING

In the meanwhile, during the 1951-1954 period, a completely different type of reactor support experiments took place in the 189-D Building. In November 1951, the exponential physics experimental facility at the Hanford Works burned to the ground in an unforeseen accident.[30] At that time, the 326 Pile Technology Building, the new facility planned to hold exponential physics experiments was under construction but not nearly complete. Yet, exponential physics work (known as secret project P-12) was considered essential to rapid and competitive reactor development at HW, especially to key and timely decisions involving lattice spacing, process channel size and fuel element size in the new K Reactors.[31]

For these reasons, exponential physics experiments were moved into the 189-D Building in late 1951. As of November 23, the presence of the P-12 work made this laboratory an "exclusion area." Uranium was clad ("canned") in the 108-D Building, a former WWII chemical pump house, and was loaded into eight-foot graphite stacks pierced with process holes of various sizes and lattice configurations, and situated in the 189-D Building. Each cube sat on an

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28 Taylor, HW-34229, pp. 6, 12, 18-19.

29 Hale, HW-24800-103, pp. 7-11; and Forsman, HW-35794, pp. 3-5.

30 Riggs, HW-22936.

31 Greninger, HW-14110, pp. 57-62.

additional 20-inch graphite base and required 30-35 tons of graphite (in total), and 5-15 tons of uranium. Small, flat indium foils and some cylindrically mounted indium foils, along with some gold foils, were inserted as the measurement devices. The radioactivity induced in these foils could be measured after each experiment, to determine the diffusion length in various lattices, the amount of buckling (neutron leakage from one lattice cell to the next), and other variables. Borontrifluoride (BF_3) neutron counting devices also were used. In some tests, four radium-beryllium (Ra-Be) neutron sources were placed in a diamond array in the base of the pile, each source having the strength of 6.6×10^6 neutrons per second. Some experiments were performed with wet graphite, to determine the effect of this variable on numerous other factors. Shielding was accomplished with lead bricks, built up as walls or sometimes as "caves," to contain the radioactivity.[32]

The exponential physics experiments continued in the 189-D Building throughout 1953, and included (in addition to the above) investigations of the "blackness" (neutron absorbing ability) of various foils, tests with hollow fuel elements (both water filled and dry) and with enriched fuel elements ("C" elements, or those containing 4.3 percent uranium 235 by weight), resonance escape, the amount of neutron streaming throughout unmachined or damaged graphite within reactors, and temperature correlations between neutrons and graphite. In the last quarter of the year, a small exponential pile was built, 48 inches wide and long, and 61.9 inches tall. It sat on an additional 19.9-inch graphite base. It was surrounded on all sides by a cadmium sheet that acted as a neutron reflector, and four Ra-Be neutron sources were placed in a symmetrical diamond array in the base of the pile. The smaller pile was desired in order to conserve graphite and uranium, but physicists previously had been afraid of poor extrapolation ratios between the buckling rate of such a small pile and that of a full-size reactor. However, they found a way to measure the correlation ratio and to compensate for the differences in their calculations. Many of the experiments conducted in this pile and in the larger piles in the 189-D Building contributed to a better understanding of the effects of cooling water on the reactivity or buckling in graphite-uranium lattices. The ultimate objective, as with almost all pile-related experiments at HW during that period, was to find ways to safely increase reactor power levels. During the first quarter of 1954, approximately 50 percent of the exponential physics equipment, material and personnel in the 189-D Building moved into the new 326 Building. The remainder of the personnel and equipment completed the move later that year.[33]

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32 Alexander, HW-22886, p. 20; and Kreusi, Duvall and Davenport, HW-22922, pp. 7-8; and Faulkner, Davenport and Duvall, HW-24724, pp. 7-9; and Faulkner, Davenport and Duvall, HW-27354, pp. 12-16; and Faulkner, Davenport and Duvall, HW-27636, pp. 7-10; Davenport, Faulkner and Ozeroff, HW-30508, p. 7; and Faulkner, Davenport and Duvall, HW-29596, p. 11; and Gerber, WHC-MR-0388, pp.149-151.

33 Faulkner, Davenport and Duvall, HW-28283, pp. 12-13; and Faulkner, Davenport and Duvall, HW-28610, pp. 8-11; and Farrand and Lloyd, HW-29453; and Faulkner,

CORROSION, THERMAL HYDRAULICS AND HEAT TRANSFER STUDIES CONTINUE IN 185/189-D

In March 1955, the 105-D Flow Laboratory closed, as its development activities transferred to the new 1706-KE Water Studies Semi-Works. This new facility contained state-of-the-art (in that era) equipment that rendered the 105-D Lab virtually obsolete, especially in the field of recirculation studies.[34] However, the re-fitting of the older Hanford reactors with recirculating cooling systems was so economically prohibitive that corrosion, heat transfer and other studies on the existing systems remained important.[35]

Throughout 1955, several key experiments were conducted in the 185/189-D Building to investigate coolant variables. One such trial evaluated a new type of wire-reinforced Teflon[36] connector assembly (connecting the inlet water supply with process tubes) for use in the K Reactors. A nine-tube cycling machine, duplicating the inlet-face crossheader and nozzle assemblies used on the K Reactors, was emplaced. Of the nine connectors, six had been pre-defected by cutting some of the reinforcing wires, twisting, bending and other rough handling and abuse, and gripping in the jaws of a tensile testing machine. The other three connectors were undamaged. Then, coolant flow was cycled through all nine connector assemblies at different pressures and temperatures, to simulate a full process tube thermal expansion cycle that took place during K-Pile startups and shutdowns. Cavitation tests and other tests also were run.[37]

Other important 1955 tests involved the electrically heated heat transfer mock-up. It was modified during the year to permit investigations of flow, temperature and pressure conditions during such transient events as power surges, steam loss, plugging of the screens that prevented the entry of solid materials into the reactor tubes, and downstream plugging of tubes. The equipment modifications allowed boiling and burnout tests to be conducted up to 2,000 pounds per square inch (psi) and 1,100 kilowatts (KW). Boiling studies continued to be important as reactor operators wanted to determine whether or not the new "trip-before-instability" limits indeed represented the furthest outpost on the frontier of safety. The flow characteristics of various orifice sizes and designs, and of other flow restriction and measurement devices, was examined in many tests. The objective was to find designs that minimized pressure loss at the flow measurement (restriction) point, and thus that maintained more water pressure within the process tubes without additional pumping at the inlet end. The knowledge gained from these experiments and from in-pile tests was

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Davenport and Duvall, HW-29596, pp. 11-15; and Davenport, Faulkner and Ozeroff, HW-30508, pp. 6-8; and Staff, Physics Unit, HW-31351.

[34] Pile Technology Section, Engineering Department, HW-41877, pp. 30-31, 50; and Carson, Purcell and McEwen, HW-30907 RD, pp. 13-14.

[35] Heacock, HW-40837.

[36] Teflon is a trademark name of the DuPont Corporation of Wilmington, DE.

[37] Rudock, HW-37090 Rev. 1.

reported to the Atomic Energy Commission (AEC) as being important in establishing safe operating power levels. Also, it soon was incorporated into the major reactor modification projects that took place at Hanford between 1955-1962. New venturi tubes that replaced the orifices inside the inlet crossheaders smoothed and distributed water flow such that pressures losses of only five percent (as compared to 40 percent with some of the older devices) occurred. Additionally, flow laboratory studies, as well as in-pile tests during 1955 resulted in changes to the Hanford Water Process Specifications, lowering the coolant Ph to 7.3 in 1955 and to 7.0 in 1956.[38]

BOILING CURVE STUDIES LEAD TO FURTHER REVISIONS IN HW PROCESS SPECIFICATIONS

In January 1956, additional generating capacity was added to the 185/189-D Building once again. Throughout that year, investigations of the pressure-flow relationships within the process tubes, known as boiling curve studies, were conducted constantly, using many variables related to higher temperature and to temperatures generated at specific points along the tubes. Other experiments tested the flow versus pressure drop characteristics of various orifice assemblies. It was suspected that some of the orifice assemblies in the HW reactors had been reversed inadvertently during installation and were causing cavitation within the process tubes. The trials in the 185/189-D facility aimed at detecting such reversals by studying flow conditions.[39] A very important series of 1956 tests continued the testing of various devices to allow for charging and discharging ("C-D") of the Hanford reactors while they were operating. The time-saving efficiency of such equipment had been sought for several years, but the first successful trials of full "flush charging" machines took place in the 185/189-D Building.[40] Further experiments were conducted as flush charging and "flow seating" seemed to cause a rise in fuel rupture rates, and as the curvature of process tubes emerged as an important factor in such operations.[41]

Additionally, a new hydraulic tube puller, designed to remove process tubes from the reactors when the tubes were not so badly damaged that splitting was required, was tested successfully in the 185/189-D Building.[42] Other tests

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38 Pile Technology Subsection, Engineering Department, HW-41877, pp. 7-8, 21-22, 30; and Robb, HW-28784; and Trumble, HW-44708, Vol. 1; and Morris, HW-44473; and Waters, HW-47197; and deHalas, HW-45045; Greager, HW-36621, p. 3; and Geier and VanWormer, HW-75609. See also: Hanford Site Project Records for Projects CG-558, CG-600 and CG-775, all entitled "Reactor Plant Modifications for Increased Production."

39 Batch and Toyoda, HW-42469-B, pp. 2-5; and Reactor and Fuels Research and Development Operation, HW-47810, pp. 28-29.

40 McCarthy and VanWormer, HW-43464; and Lovington, HW-36224; and Carlson and Trumble, HW-63471.

41 Arneson and VanWormer, HW-41400; and Arneson, HW-41661.

42 Department Managers, HW-42219, pp. Fb-14, Fb-21.

evaluated the integrity of a prototypical design in "pigtails" (the coiled, aluminum tubing connectors between the crossheaders and the individual tube nozzles at the front and rear of the Hanford reactors).[43]

During 1957, many important and timely experiments took place in the 185/189-D facility, nearly all related to boiling curves, "boiling burnout," and to locating the upper temperature limits for coolant water passing through and exiting the Hanford reactors. A team of engineers assigned to these experiments in January stated: "Boiling heat transfer is of considerable current interest. Of particular importance is the characterization of conditions called burnout. This is most commonly considered as a point at which transition from nucleate boiling to firm boiling occurs...If the temperature difference becomes excessive at the burnout point the heated surface will be destroyed by melting."[44] A 21-foot horizontal test section (a copper-nickel alloy rod centered in a stainless steel pipe), a recirculating pump, two electric preheaters and a heat exchanger were constructed in the 185/189-D Building, and heated via d-c current from electric generators. The copper-nickel allow was chosen because its thermal properties were thought be resemble those of uranium. Heat fluxes from 100,000 to 396,000 BTU (British Thermal Units) per hour per square foot were measured. As water was passed through the assembly, the transition from nucleate boiling to bulk boiling was found to be smooth.[45]

Once the basic parameters of the transition to bulk boiling had been established, a long series of experiments that simulated process tube plugging began. Cameras, recorder charts, and other monitoring devices measured temperature, pressure and flow at various points along tests assemblies that used "BDF" reactor-type orifices, KE-KW reactor-type fittings, nozzles, pigtails and venturis, and many other conditions. Change in capacitance was measured by a (then) state-of-the-art sensing device known as a "series capacitive-inductive circuit". The trials were crucially important at that time because a series of major modifications for power increases just was being completed at the oldest reactors, and was being designed for the C, KE and KW reactors. There was a critical need to gain understandings of the conditions that would result from sudden or gradual plugging of the process tubes at the new power levels. Because the power level increase modification projects at the five oldest reactors all were grouped under Project CG-558 in the Hanford Site project records, and the C-Reactor modifications were labeled as Project CG-600, these hydraulic experiments became known as the "post-CG-558-600" series. Many different

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Note: In most cases, removal of damaged process tubes at Hanford was accomplished with an equipment piece developed onsite and known as a tube splitter. It was an internal probe that progressively widened until the tube metal parted. Then, individual tube lengths were pulled out.

43 Bell, HW-43394.

44 McEwen, Batch, Foley, and Kreiter, HW-47892, p. 3.

45 McEwen, Batch, Foley and Kreiter, HW-47892, pp. 3-4; and Operation Managers, HW-47943, p. A-7.

test assemblies were constructed, and trials were run at various kilowatt (KW) levels.[46]

HANFORD PROCESS SPECIFICATIONS AGAIN REVISED DUE TO 185/189-D WORK

One result of these 1956-57 tests in boiling curves was that the trip-before-instability limit was replaced with the "trip-after-instability" (TAI) limit for the C, KE and KE reactors in late 1957. Adoption of the TAI limit in the Hanford Process Specifications meant that at these three reactors, fitted with newer and more favorable coolant equipment, the automatic shutdown gauges that monitored water flow were set to activate only after nucleate boiling had begun in the coolant exiting the process tubes. The higher temperature limitations thus allowed increased power levels and increased plutonium production, within margins considered to be safe.[47]

Other studies carried out in the 185/189-D facility during 1957 included continued orifice and venturi investigations. A variety of orifice configurations were tested for possible replacement of those then in use in the fringe zones of the KE-KW Reactors. Also, corrosion studies were performed on the new Zircaloy-2 alloy[48] that was being evaluated as the potential replacement material for Hanford's reactor process tubes.[49]

Throughout 1958, tests simulating the sudden or gradual loss of flow through a reactor process tube remained important in the 185/189-D facility. Many of these experiments were conducted in order to validate the safety standards then in place regarding temperature and pressure. Some of the tests were performed using drilled solid dummy fuel elements and/or internally and externally cooled (I&E) dummy fuel elements. Fuel elements having complete cylindrical holes down their centers were under intense study at HW at that time, due to their greater cooling capacity over traditional solid elements. Within a short time, HW made a nearly complete conversion to I&E fuel elements, thus enabling reactor operations at higher power levels within a margin of temperature safety. Other experiments later in the year in the 185/189-D Building were run to characterize the situation that would occur with reverse water flow through a process tube. This condition was postulated to happen if a front hydraulic connector were completely lost during pile operations. Additional trials were

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[46] Hesson and Thorne, HW-48519; and Pound, HW-48759; and Operation Managers, HW-49419, p. A-11; and Hesson and Thorne, HW-49813; and Operation Managers, HW-49752, p. A-9; and Batch, Hesson, Thorne and Toyoda, HW-50323; and Pound and Busselman, HW-52340; and Batch, Hesson and Thorne, HW-52424-A; and Hesson and Thorne, HW-52424-B; and Toyoda and Calkin, HW-53593; and Operation Managers, HW-53299-DEL, p. A-15; and Hesson and Thorne, HW-54329.

[47] VanWormer, HW-64415.

[48] Zircaloy-2 is composed largely of zirconium, with additional small percentages of iron, chromium, nickel and tin.

[49] Operation Managers, HW-47943, pp. A-4, A-6.

executed to characterize conditions following the loss of a rear pigtail. Upon completion of the latter series, the test engineers concluded: "The experimental program demonstrated that the present protection procedures are adequate."[50]

A new development in the 185/189-D laboratory during 1958 included the building of a high pressure heat transfer apparatus (Project CG-834) that would be able to operate at 2,500 psi at 650 degrees F (Fahrenheit), and the receipt of silicon rectifier power generators to power the new equipment. The silicon rectifiers, actually installed in early 1959 in Project CG-661, generated 32,000 amps (amperes) at 100 volts d-c. Previous to these equipment upgrades, the operating levels of the older pressure apparatus had never exceeded 900 psi at 450 degrees F. With the addition of the new equipment, the older apparatus became known as the "low-pressure" facility. Also in 1958, a "momentum chamber" designed to conduct two-phase measurements of steam and water ratios, was constructed in the 185/189-D Building, and a mockup of the discharge chutes on the recirculating tubes in the KER facility was built in order to determine flushing pressures needed in KER discharge activities.[51]

NPR EXPERIMENTS BEGIN

Additional key experiments were begun during 1958 in the 185/189-D facility in the development of heat transfer data for the New Production Reactor (NPR) that later was named N-Reactor. Other tests defined the characteristics present when Poison Column Control Facility (PCCF) tubes were inadvertently discharged. PCCFs were supplementary control devices installed in some of the Hanford reactors in the mid-1950s. They consisted of ball-valves placed in the nozzles of selected tubes, so that additional neutron-absorbing materials could be charged or discharged during operations in order to flexibly vary the reactivity in ceratin reactor zones. Still more trials in the 185/189-D facility that year measured the response time of various resistance temperature detectors (RTDs) just installed as part of upgrades on the existing Hanford reactors.[52]

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50 Waters and Horn, HW-54590; and Operation Managers, HW-55162-DEL, pp. A1-19 -20; and Waters, HW-55269; and Fitzsimmons and Hesson, HW-56621; and Operation Managers, HW-56914, pp. A1-15-16; and Operation Managers, HW-57636, p. A1-15; and Operation Managers, HW-58661, p. A-14; and Operation Managers, HW-58019, p. A-16.

51 Operation Managers, HW-55162-DEL, pp. A1-20-21; and Operation Managers, HW-56914, p. A1-16; and Operation Managers, HW-60505, p. A-17; and Operation Managers, HW-57636, p. A1-16; and Operation managers, HW-58019, p. A-17; and Operation Managers, HW-58244, p. A-16; and Batch and Toyoda, HW-65722; and Operation Managers, HW-58661, p. A-15.
Note: The KER facility was a underground test facility located in the KE Reactor area. Circulation, heat transfer and other tests using radioactive materials were conducted in the KER facility.

52 Operation Managers, HW-55162-DEL, p. A1-21; and Operation Managers, HW-56914, p. A1-16; and Lovington, HW-36224; and Carlson and Trumble, HW-62471; and Operation Managers, HW-58019, p. A-16.

During 1959, many more unique development experiments went forward in the 185/189-D Building. The new high pressure heat transfer apparatus was used to test simulations of a prototypical wire-wrapped, seven-element cluster of fuel elements being considered for use in the NPR. Each element in the cluster was very thin (0.625 - 0.704-inch diameter), 35-45 inches long, and equally spaced in a 2.067 - 2.70-inch horizontal flow tube. As such, the heat transfer and flow properties of these elements were far different from those of the solid or the I&E elements previously used in Hanford's reactors. Understandings of every characteristic of the new elements was essential if they were to be recommended for the NPR, so trials continued throughout the year.[53]

Additionally, the low pressure apparatus in the 185/189-D facility was modified for the execution of numerous tests in the continuing study of flow-loss events in the older reactors. These studies led to repeated increases in the operating power levels, and thus to higher plutonium production rates at HW. The two-phase flow experiments in steam and water mixtures also continued, and further work was done to simulate conditions in the KER water loops and to establish margins of safe operations for those facilities.[54] Also, a so-called "slug-buster" was emplaced near the middle-north end of the 185-D Building. This small facility tested "green" (unirradiated) uranium fuel elements and their claddings until they failed or ruptured. The purpose was to support the development of many types of new fuel claddings and configurations then being considered at HW. Using a d-c power supply, electrodes were clamped onto the fuel elements, current was passed through them to heat them as water was running past them in a tube. Various measurements then were taken as the failures occurred. This small facility operated until it was replaced by the new 330 Building (the Fuel Element Rupture Tests Facility) in 1962.[55]

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53 Operation Managers, HW-59099, p. A-17; and Operation Managers, HW-59463, pp. A-16-17; and Operation Managers, HW-59717, p. A-22; and Operation Managers, HW-60233-A, p. A-13; and Operation Managers, HW-60505-A, p. A-18; and Operation Managers, HW-63303, p. A-19

54 Operation Managers, HW-59099, pp. A-17-18; and Operation Managers, HW-59463, pp. A-15-17; and Operation Managers, HW-61374-A, pp. A-17-18; and Operation Managers, HW-59717, pp. A-12-13; and Operation Managers, HW-60233, pp. A-21-22; and Fitzsimmons and Hesson, HW-60287; and Operation Managers, HW-60505-A, pp. A-17-18; and Operation Managers, HW-60846, pp. A-17-18; and Operation Managers, HW-61702, pp. A-16-17; and Cremer, Fitzsimmons and Hesson, HW-61929; and Operation Managers, HW-62012-A, pp. A-17-18; and Operation Managers, HW-62587-A, pp. A-17-18; and Operation Managers, HW-62899-A, pp. A-15-17; and Operation Managers, HW-63303, pp. A-18-20; and DeNeal, DUN-6888, p. 49.

55 Operation Managers, HW-58244, p. A12; and Operation Managers, HW-59717, p. A-13; and Operation Managers, HW-60846, p. A-14.

Note: The experiments in various fuel claddings and configurations at HW during these years are too numerous to include here. This is a separate topic.

PRTR EXPERIMENTS ADDED TO 185/189-D FACILITY

Another very important series of tests conducted in the 185/189-D facility throughout 1959 supported development of Hanford's Plutonium Recycle Tests Reactor (PRTR). The PRTR was part of President Eisenhower's "Atoms for Peace" program, and was a non-defense reactor designed to test mixed oxide fuel blends for future use in commercial power reactors. The PRTR was heavy-water moderated, and operated with 67 fuel elements that each consisted of a cluster or "bundle" of 19 individual fuel rods. Vibration-packed powders and pellets (of plutonium oxide, uranium oxide, magnesium and other blends) made up the fuel inside the rods.[56] Obviously, with all of the vast differences between these new types of fuels and the reactor fuels previously used at HW, there was a great need for new understandings of heat transfer, consequences of loss of flow, sub-cooled burnout, pressure drop, pump capacities, and multiple other factors. In the 185/189-D Building, mock-ups of many of the PRTR components were built and tested throughout 1959.[57]

FULL-SERVICE THERMAL HYDRAULICS LABORATORY

By 1960, the 185/189-D Thermal Hydraulics Laboratory was one of the few "full-service" facilities of its type in the nation. It contained a large shop area wherein most test assemblies were machined, lathed, welded, and assembled. Instruments and electrical components for the experiments also were fabricated and fitted within the building. Instrument calibration equipment, an analog computer, and a 4,000-square foot storage area also were maintained within the facility. Steam connections existed from the 184-D Power House, and both raw and process water were supplied directly from the 183-D Filter Plant and Chemical Treatment Building. A process sewer line carried used water from the experiments out to a holdup crib (earth percolation basin) near the Columbia River.[58]

The high pressure heat transfer apparatus within the 185/189-D facility could be modified to accommodate horizontal or vertical test sections, and could test fuel element models configured as single rods, several rods in a cluster, or the new "tube-in-tube" design being tested for the NPR. It was a stainless steel, recirculating facility with a deionized water coolant obtained from steam condensate and treated in anion-cation equipment. The maximum coolant

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56 AEC/GE Study Group, GEH-26434, pp. 3.12-3.17; and HEDL Facilities catalog (1971), pp. 309 (3 pp.).

57 Operation Managers, HW-59099, pp. A-29-30; and Operation Managers, HW-59463, pp. A-26-27; and Operation Managers, HW-61374-A, pp. A-33-34; and Operation Managers, HW-59717, pp. A-21-22; and Operation Managers, HW-60233, pp. A-28-29; and Operation Managers, HW-60505-A, pp. A-31-32; and Operation Managers, HW-60846, pp. A-32-33; and Operation Managers, HW-61702, pp. A-30-31; and Operation Managers, HW-62012-A, pp. A-30-31; and Operation Managers, HW-62587-A, pp. A-28-30; and Operation Managers, HW-62899-A, pp. A-27-32; and Operation Managers, HW-63303, pp. A-30.

58 Batch and Toyoda, HW-65722, pp. 12-13; and Thorne, BNWL-SA-1770.

circulation rate was 250 gpm. It continued to investigate subcooled and boiling burnout, single and two-phase pressure drop, and related studies for the NPR, PRTR, and for other planned Hanford test reactors. During 1960, a test section consisting of an electrically heated rod in a glass tube with annular water flow was built to observe and photograph circumferential temperature variations due to flow eccentricities. Additionally, as the co-extruded tube-in-tube fuel element design that eventually was adopted for the NPR gained popularity as opposed to the seven-rod fuel element clusters, a full-scale, experimental heat transfer test section that simulated the downstream half of a tube-in-tube charge in the NPR was built on the mezzanine of the 189-D portion of the laboratory. The silicon rectifiers used for heat generation power also were modified during the year.[59]

Studies in support of the PRTR also continued in the high heat transfer apparatus during 1960, including investigations of local heat transfer coefficients on the surfaces of fuel elements in the 19-element clusters, hydraulic stability of coolant channels, protection against inadequate cooling in the event of a process tube leak, boiling burnout conditions, two-phase pressure drop in discharge piping, and flow-controlling orifices. For these experiments, a special test section of 19 Inconel[60] tubes, each containing a machined ceramic insert to prevent collapse of the extremely thin-walled tube, was built, and the recirculating pump in the high heat transfer apparatus was replaced. The boiling burnout trials proved to be especially important, in that they demonstrated that several tubes could rupture and melt without being detected by the thermocouples on the tube walls. It was surmised that the tube melting had shorted the electrical connections in the thermocouples. Therefore, fundamental safety changes could be suggested for actual PRTR operations.[61]

The low pressure heat transfer apparatus in the 185/189-D Building also continued its studies in the performance characteristics of the existing Hanford production reactors (B, D, F, DR, H, C, KE and KW). It was a recirculating facility consisting of an aluminum process tube lined with electrical resisting phenolic resin to prevent electrical leakage from the tests element to the housing tube.

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59 Batch and Toyoda, HW-65722, pp. 3-6; Toyoda, HW-71389; and Thorne, BNWL-SA-1770; and Operation Managers, HW-63740-A, pp. A-16-17; and Operation Managers, HW-64108, pp. A-15-16; and Geering, HW-66267; and Operation Managers, HW-65459, p. A-18; and Operation Managers, HW-65854, p. A-19; and Operation Managers, HW-66237, p. A-14; and Operation Managers, HW-67532, pp. A-16-17; and Operation Managers, HW-67954, p. A-17.

60 Inconel is a trademark of Inco Alloys International, Inc. It consists primarily of nickel, but also contains chrome, iron and trace amounts of other metals.

61 Operation Managers, HW-63740-A, pp. A-28-31; and Operation Managers, HW-64108, pp. A-28-34; and Operation Managers, HW-65459, p. A-26-29; and Operation Managers, HW-65854, p. A-29; and Operation Managers, HW-66237, p. A-24; and Operation Managers, HW-66644-DEL, pp. A-27-28; and Operation Managers, HW-66960-DEL, p. A-26; and Operation Managers, HW-67254, p. A-31; and Operation Managers, HW-67532, pp. A-26-27; and Operation Managers, HW-67954, pp. A-28-29.

Downstream of this heated portion of the facility was a reactor nozzle, outlet fittings, and header arrangement that could be varied to simulate numerous actual operating conditions among the eight reactors. Parallel to the main section was a shorter test section that could be changed out to consist of various metals or glass. It was used to investigate boiling, flow mixing, channeling, stratification of vapor phase, pressure drop, and other conditions within process tubes when orifices, pumping rates, temperatures and other factors were varied.

During 1960, special attention was given to various designs in process tube outlet connectors, and the data supplied by the 185/189-D facility experiments was important in the decision to modify these fittings to allow for increased reactor coolant flow. Additionally, prototypical fuel element projections (flat or "suitcase handle-type" projections) were studied, as were new inlet nozzle assemblies proposed by reactor equipment development personnel. Tests with eccentrically formed fuel elements continued, as did critical flow stoppage experiments under multiple conditions, and simulated electrical power failure trials. The results of these latter tests were presented to the AEC as evidence of the safety of proposed power level increases at the Hanford reactors. Evaluations of the potential organic reactor coolant monoisopropylbiphenyl (MIBP) also took place in another miniature, low pressure Organic Heat Transfer Apparatus.[62]

TESTS CONTINUE IN 185/189-D IN SUPPORT OF EXISTING REACTORS, NPR AND PRTR

Throughout the years 1961-1963, three main types of experiments continued in the 185/189-D Building -- those supporting the existing Hanford production reactors, the NPR and the PRTR. Questions of ongoing importance to the existing reactors concerned two-phase (steam-water) critical flow phenomenon within process tubes, the effects upon coolant temperatures of eccentrically placed or configured fuel elements within tubes, new types of seal inserts within rear header fittings and nozzles, and various types of fuel element supports. Boiling burnout studies also remained salient, and major modifications were made to the low pressure heat transfer apparatus in early 1963 to accommodate these experiments. A deaerator, a demineralizer, and a new preheater were installed on this equipment in order to provide greater flexibility and control over the coolant conditions being studied. The consequences of locating both thermocouples and RTDs in the outlet elbows of process tubes, as

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62 Batch and Toyoda, HW-65722, pp. 6-9, 11; and Thorne, BNWL-SA-1770; and Operation Managers, HW-63740-A, pp. A-16-17; and Operation Managers, HW-64108, pp. A-14-15; and Operation Managers, HW-65459, pp. A-15-17; and Operation Managers, HW-65854, pp. A-18-20; and Waters, HW-63756 1; and Waters and Fitzsimmons, HW-67139; and Operation Managers, HW-66237, pp. A-13-14; and Operation Managers, HW-66644-DEL, pp. A-15-17; and Operation Managers, HW-66960-DEL, pp. A-13-15; and Operation Managers, HW-67254, pp. A-17-19; and Operation Managers, HW-67532, pp. A-16-18; and Trumble, HW-84894, p. 19; and Operation Managers, HW-67954, pp. A-16-18.

well as the effects to be expected if a broken "spline"[63] should lodge in a K-Reactor outlet nozzle, were evaluated.[64]

One outcome of the improved understandings of burnout conditions achieved through 185/189-D facility studies resulted in a change in the Hanford Process Specifications. As of December 1962, the power level limitations of four of the oldest reactors became based not on MW level but on the bulk exit water temperature. This ruling was reversed a year later, when the power levels for the eight Hanford single-pass reactors became based on the highest MW level previously achieved on a sustained basis. However, in March 1964, the power level limits for the six oldest reactors again reverted to a bulk outlet water temperature limit of 95 degrees C (Centigrade).[65]

Studies conducted in the 185/189-D Building in support of NPR development focused on crucial boiling burnout determinations. Numerous experiments were carried out under varied conditions in the full-size mockup of the downstream half of a NPR process tube located on the 189-D mezzanine. General information also was developed on the heat transfer characteristics of the tube-in-tube fuel elements, the effects of system pressure decreases, and pressure drop data for two-phase flow conditions (both steam-liquid and liquid-liquid).[66]

After the PRTR started up in July 1961, many additional experiments went forward in the 185/189-D facility to address operating anomalies and to verify the feasibility and safety of tests planned in the actual reactor. When PRTR tube flow meters began to fluctuate, investigations of sensing lines, suppression devices, throttling valves and other factors were undertaken. Heat transfer and

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63 A "poison spline" was a long, thin strip of neutron-absorbing metal, usually aluminum-boron, used for supplementary reactivity control in the Hanford production reactors beginning in the mid-1950s. A spline was inserted through a slit in the seal of the front process tube cap, and pushed down the tube under the active fuel charge, in order to selectively alter the flux distribution.

64 Zaloudek, HW-68934; and Operation Managers, HW-70658-DEL, pp. A-11-12; and Operation Managers, HW-72590, pp. A-14-15; and Operation Managers, HW-82906, pp. A-14-15; and Waters, Anderson, Thorne and Batch, HW-73902 Rev; and Waters, HW-63756 4; and Operation Managers, HW-75925, p. A-15; and Section Managers, HW-76596, p. A-16; and Section Managers, HW-77397, pp. A-16-17; and Zaloudek, HW-77594; and Zaloudek, HW-79463 Rev; and Section Managers, HW-79377, pp. A-14-16; and Morris, HW-39792.

65 DeNeal, DUN-6888, pp. 21, 23, 25.

66 Operation Managers, HW-70658-DEL, p. A-12; and Anderson, Thorne and Batch, HW-71784; and Operation Managers, HW-72590, p. A-15; and Operation Managers, HW-82906, p. A-15; and Operation Managers, HW-75925, p. A-14; and Section Managers, HW-76596, pp. A-15-16; and Section Managers, HW-77397, p. A-17; and Anderson, Thorne and Batch, HW-77470; and Section Managers, HW-79377, pp. A-12-14.

boiling burnout information under multiple and varied conditions was needed, and a special, 19-element boiling burnout test section was built in early 1962 for this purpose. This test assembly failed after just 18 experimental burnout data points were obtained. It was removed and repaired in August, 1962. When PRTR tube powers were increased in 1963, boiling burnout studies were run once again under the new conditions. Loss of pumping power experiments likewise were carried out. Due to the incremental loading process used to fabricate PRTR fuel, non-uniform distribution of the plutonium oxide (and hence of surface heat flux) sometimes occurred. Many studies were conducted in the 185/189-D laboratory to determine heat transfer characteristics for such non-uniformly enriched fuel. The spacing between the individual fuel elements with the cluster also was found to have a vast effect on coolant temperatures.[67]

1964-1965 BRING MAJOR CHANGES TO HANFORD SITE AND REACTOR OPERATIONS

The years 1964-1965 witnessed significant changes in reactor operations at Hanford. On January 8, 1964, President Johnson announced a decreased national need for special nuclear materials. Soon afterward, it also was announced that the HW reactors would begin to close and that the G.E. Hanford Company would leave the Site, both activities to be implemented in a phased sequence. The first reactor closure (DR) came in December of that year, and in 1965 both H and F Reactors closed. As of January 1, 1965, Battelle North West Laboratory (BNWL - an offshoot of the Battelle Memorial Institute of Columbus, Ohio) took over the functions of the former Hanford Laboratories Operation as the research division for much of Hanford. With this transfer, the 185/189-D Building was divided with a half-wall approximately in the middle. BNWL conducted the thermal hydraulics and flow laboratory work in the north sector of the building in support of both the HW and offsite reactors. The G.E. Hanford Company retained the south portion of the building, using it for storage and HW reactor materials and component development testing until it transferred its responsibilities for the eight older reactors to Douglas United Nuclear Corporation (DUN) in September 1965 and for N-Reactor (the NPR) in July 1967. DUN then continued to execute reactor support testing during its tenure at the Hanford Site. N-Reactor began operations in December 1963, and the PRTR experienced a major operating accident in September 1965, and was shut down until the spring of 1966. After that time, the PRTR never again conducted full-scale operations,

67 Koberg and Purcell, HW-SA-2556; and Hesson, Thorne and Batch, HW-70711; and Operation Managers, HW-70658-DEL, p. A-21-22; and Operation Managers, HW-72590, pp. A-41-42; and Hesson, Fitzsimmons, Waters and Batch, HW-73395; and Operation Managers, HW-74522, p. A-45; and Zaloudek and Hesson, HW-76115; and Operation Managers, HW-75925, p. A-22; and Section Managers, HW-76596, p. A-25; and Hesson, Thorne and Batch, HW-70711 Rev; and Amos and Zaloudek, HW-77681; and Section Managers, HW-77397, p. A-27; and Waters and Fitzsimmons. HW-SA-3086; and Waters, Hesson, Fitzsimmons and Batch, HW-77303.

although it did carry out a "batch core experiment" for about 18 months beginning in July 1966.[68]

Throughout 1964, work in the 185/189-D Building continued without substantial change from the work conducted during 1961-63, except that studies concerning the single-pass HW reactors focused on the newer ones (KE and KW) that would be the last to close. For N-Reactor and the PRTR, experiments focused on two-phase flow mixtures in high pressure systems and their relationships to reactor safety, boiling bumout (including comparisons of data taken in vertical and horizontal positions), the pressure drop effects of obstructions within process tubes, and the temperature transient conditions resulting from a break in an N-Reactor inlet connector. For this work, the high pressure heat transfer apparatus was operated sometimes at 3,800 KW, its highest level to that date. One key result of the PRTR studies thermal hydraulics studies in the 185/189-D Building was the conclusion that power density in the core "could reasonably be increased up to 3.6 times the present level without encountering flow instability and without relaxation of the boiling burnout safety limits." This finding, made early in the year, was a crucial precursor to some of the operating decisions for PRTR experiments that followed. Preliminary studies also were begun in 1964 to define operating characteristics and parameters for the High Temperature Lattice Test Reactor (HTLTR), and dry nitrogen gas-cooled test reactor that was authorized at HW in 1963 and constructed during 1966-1967.[69]

Throughout 1965-1967, studies in the 185/189-D Building concerned most of the same topics as those examined during the early 1960s, but with decreased emphasis on the single-pass reactors and the PRTR, and increased emphasis on N-Reactor. Developmental studies in support of the HTLTR remained minor. Among the subjects investigated in 1965 was a thorough study of the hydraulic characteristics of the N-Reactor primary coolant loop, the consequences of fuel element plugging within N-Reactor tubes, the choking condition known as critical flow that occurred when steam and water were simultaneously discharged to the atmosphere adjacent to a pipe fitting, riser-to-riser pressure drop, and pressure differentials among the three subchannels of the N-Reactor tube-in-tube fuel configuration. Interchannel flow between fuel elements in N-Reactor tubes, the effects of variations in seal rings used in the inlet ends of fringe tubes, and the

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68 "Hanford To Cut Back...," p. 1, January 8, 1964; and DeNeal, DUN-6888, p. 42; and Sinclair, "Battelle-Northwest...," May 1968; Hylbak, RL-GEN-1180, Sup 1, p. 67; and Purcell, BNWL-SA-557; and Richmond and Pollock, BNWL-726.

69 Zaloudek, HW-SA-3340; and Zaloudek, HW-80535 RD; and Section managers, HW-80560, pp. A-15-16, A-25-26; and Hesson, Fitzsimmons and Batch, HW-80523 Rev 1; and Fitzsimmons, HW-80970 Rev 1; and Anderson, Batch, Thorne and Fitzsimmons, HW-80692; and Section Managers, HW-83000, pp. A-11-12, A-30-31, B-17; and Hesson, Fitzsimmons and Batch, HW-83443; and Rowe, Anderson, and Thorne, HW-84104; and Section managers, HW-84591, pp. A-7-9, A-19-20, A-37; and Hanthorne, BNWL-CC-225, Rev 1.
Note: The direct quotation is from Section Managers, HW-80560, p. A-25

thermal hydraulic parameters of "co-product" (tritium-producing) lithium aluminate fuel elements also were studied with vigor. Numerous pressure drop, temperature and other measurements were taken in the mockup loops.[70]

In 1966, steam-generating equipment and tie-ins were completed at N-Reactor and it became the first dual-purpose (defense and electric power production) reactor in the nation.[71] During 1966-1967, many experiments conducted in the 185/189-D laboratory supported this unique reactor, Including vibration testing of the co-product fuel elements, more pressure drop studies for N-Reactor tube-in-tube fuel, and more boiling burnout trials with both normal and co-product N-Reactor fuel. Other investigations tested cross-flow mixing between parallel flow channels within bundle fuels, departure from nucleate boiling studies with bundle fuels, and simulated evaluations of the pressure tube and fuel failure event that had occurred at the PRTR in September 1965. Further, a complete mock-up of the K-Reactor biological and thermal shields with a VSR channel opening was constructed in the 185/189-D Building, in order to conduct trials of new shield boring machines. Orifice tests to solve the recurrent problem of plugging of the flow rate sensing lines in the older reactors, as well as examinations of interchannel flow through fuel element junctions in a C-Reactor fuel model also were performed. HTLTR support experiments also included simulation work.[72]

FFTF DEVELOPMENTAL TESTING BEGINS IN THE 185/189-D FACILITY

For the most part, the 1968-1969 studies in the 185/189-D Laboratory represented continuations and variations on topics that had been examined previously in the facility. During 1968, evaluations were made of different types of springs on N-Reactor fuel elements, zone temperature monitor protection requirements designed to "scram" (shut down) N-Reactor prior to boiling burnout conditions, the thermal hydraulics characteristics of a new type of N-Reactor fuel elements (Mark IV, containing 0.947 percent U-235, as opposed to the Mark I-C fuel previously used), and of the temperature stabilizing effectiveness of "mixer-spools" used in the older reactors.[73] Studies were conducted to establish

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[70] Dickeman, HAN-90792 (RL-NRD-150-1), p. 24; and Anderson and Batch, DUN-8263; and Department Managers, BNWC-8-1, pp. A-7-10; and Zaloudek, BNWL-34; and Dickeman, RL-NRD-150-4, p. 19; and Pociluyko, RL-NRD-498; and Anderson, Batch, Thorne and Fitzsimmons, BNWL-CC-193; and Dickeman, HAN-92810 DEL (RL-NRD-150-9), pp. 28-19, 33; and Shoemaker, DUN-8264; and Dickeman, HAN-93378 DEL (RL-NRD-150-11), pp. 30-33.

[71] Hylbak, RL-GEN-1180 Sup 1, pp. 75-79.

[72] Dickeman, RL-NRD-660-1, pp. 40, 42; and BNWL-CC-500-046601, pp. 17-18, 48-49; and DUN, HAN-94154 DEL (DUN-559), pp. E-1-4; and Freshley, Wheeler, Batch and Hesson, BNWL-CC-655; and Anderson, Fitzsimmons and Thorne, BNWL-CC-729; and Fitzsimmons, Thorne and Batch, BNWL-CC-1095; and Telford, RL-GEN-1542; and Sutey, BNWL-CC-1369; and BNWL-444, pp. 29-32, 44.

[73] Mixer spools were special, two-inch long attachments with holes in them, welded onto the standard fuel elements used in the older reactors in order intermix flow streams above

general understandings of mass transfer at the solid-liquid interface of two-phase film flow within annular ducts.[74] During 1969, tests of the simulated flow monitor sensing lines continued, in preparation for an N-Reactor line replacement project that began late that year. Studies of critical flow of coolant through reactor nozzles also went forward, as did trials of variable orifice designs, examinations of the hydrodynamic drag coefficients when various obstructions were placed within flow channels, and mockups of tests that were performed that year to analyze primary loop leaks within N-Reactor. One key addition in 1969 was the beginning of developmental testing for the Fast Flux Test Reactor (FFTF), the prototype being built at Hanford for the nation's "breeder" reactor program.[75] The earliest tests evaluated an electrically heated, seven-fuel pin assembly model to determine temperature gradients between wall and central coolant channels, thermal stress levels, and potential hot spots caused by a spiral wire wrap that was planned to be used around each fuel pin.[76]

1970-1971 WITNESS END OF SINGLE-PASS REACTOR OPERATIONS AT HANFORD

The years 1970-1971 saw the respective closures of KE and KW, the last of the single-pass reactors at the Hanford Site. (D-Reactor had closed in 1967, B-Reactor in 1968, and C-Reactor in 1969).[77] With N-Reactor then the only defense production reactor still operating, all studies conducted in the 185/189-D Building by DUN supported this reactor. Studies carried out by BNWL branched into private sector and other offsite areas allowed by the research and development contract, so that BNWL carried out thermal hydraulics, flow and heat transfer investigations in support of N-Reactor, FFTF, and various other entities. During 1970-1971, DUN examined fuel flushing and movement within tubes testing for N-Reactor, different designs in fuel spacers, burnout conditions and measurements (especially focused on the zone temperature monitors), modified designs in venturis within header fittings, fuel support designs and wear characteristics, various features of the inlet connector butterfly valves used for flow control during C-D operations (the V-11 valves), leaks in the seal rings and hubs used on N-Reactor pipes, and criteria for a new horizontal safety and

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and below the fuel elements. They were needed in order to equalize the flow at the top and bottom of the cooling annulus, in order to alleviate hot spots and other temperature disparities.

[74] Shoemaker, DUN-8267; and Shoemaker, DUN-8242; and Kugler, DUN-8273; and Sutey, BNWL-CC-1534; and Sutey and Knudsen, BNWL-SA-1767.

[75] Breeder reactors are those that utilize a depleted uranium "blanket" surrounding their cores in order to capture extra neutrons that otherwise would escape during the fission process. The depleted uranium absorbs the neutrons and transmutes into plutonium. Thus, breeder reactors end their fuel cycles having produced more plutonium than the amount (in the fuel) with which they began.

[76] McCullough, DUN-5806; and Wegener, DUN-6507 RD; and Zaloudek and Moulton, BNWL-CC-1989; and Newell, DUN-8266; and Long, DUN-6327; and Stickney, DUN-6368; and Yatabe, Collingham, Hill and Thorne, BNWL-SA-2577.

[77] DeNeal, DUN-6888, p. 42.

control rod recirculation cooling system. Additionally, a complete training mockup for a major V-12 valve replacement activity planned for N-Reactor was built as Project DCE-551 in the 185/189-D facility in 1971.[78]

During the same period, BNWL conducted one last study that concerned the Hanford single-pass reactors, an examination of steady state thermal hydraulic characteristics of a fuel column mockup that had been "overbored" (enlarged) by one inch.[79] In support of N-Reactor, BNWL examined pressure losses within the fuel columns, and loss of coolant heat transfer experiments.[80] A liquid mixture of sodium and potassium known a "NaK" (a less volatile simulation of pure liquid sodium) was brought into the 185/189-D facility during this period when BNWL was evaluating the heat transfer capacities of the liquid sodium that would be used to cool the FFTF. BNWL also designed and built a 37-pin, instrumented fuel subassembly for irradiation in the Idaho National Engineering Laboratory's Experimental Breeder Reactor II (EBR-II). In late 1971, FFTF support work was taken up by a new design and construction contractor, the Hanford Engineering Development Laboratory (HEDL), and coolant mixture studies for the FFTF using water were conducted in the 185/189-D Laboratory.[81] In private contract work in support of commercial power reactor designs, BNWL also performed critical heat flux (boiling burnout) and two-phase hydraulic investigations for boiling water reactors.[82]

The years 1972-1975 saw a clear divergence in the work of the DUN and BNWL organizations within the 185/189-D Building. The DUN experiments were focused solely on N-Reactor and were taken up by the replacement operating contractor United Nuclear Industries Inc. (UNI) in 1973, while the BNWL studies supported private commercial reactor development for a variety of customers. The DUN-UNI trials mocked up many upgrade and replacement programs needed at N-Reactor, and thus allowed crafts people to practice in non-nuclear conditions the techniques they would need to use in actual radiation zones. For the first time in December 1972, an N-Reactor control rod failed due to problems

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78 Solecki, DUN-6606; and Schmidt, DUN-8244; and Robinson, DUN-7066; and DUN, DUN-AP-12-WPPSS; and Flickinger and Lander, DUN-7239; and Robinson, DUN-8241; and Peters and Schmidt, DUN-7485; and DUN, DUN-AP-22-WPPSS; and Barker and Weakley, DUN-7672; and Arnold, DUN-7699; and Bainard, DUN-7668 Rev.1; and Hanford Atomic Products Operation, HW-69000 Vol. 2, p. 4.3.3-2.
Note: The V-12 valves were three-position units that functioned to divert coolant water off of the rear risers of N-Reactor when maintenance work and other access to the rear area was required. They were replaced with spool pieces during 1975-1976.

79 Sutey, Fitzsimmons and Angle, BNWL-CC-2581.

80 Creer, Fitzsimmons, and Hesson, BNWL-CC-2463; and Sutey, Fitzsimmons and Collingham, BNWL-B-88.

81 Yatabe, Collingham, Hill, McSweeney and Thorne, BNWL-1136; and Collingham, Hill, Yatabe and Thorne, BNWL-SA-3286; and Collingham, Thorne and McCormack, HEDL-TME-71-146; and Millhollen and Sutey, BNWL-1424.

82 Sutey, Fitzsimmons, Thorne and Torobin, BNWL-SA-3724.

related to graphite distortion in the pile. An alignment block known as a T-block fell into the HCR channel, thus impeding the path of the rod. At that time, a complete simulation, duplicating in-reactor conditions as nearly as possible including graphite distortion configuration, was built in the 185/189-D facility. This mockup was scrammed a total of 1,343 times, and then was further distorted to resemble expected reactor conditions after 1985. The new configuration then was scrammed 25 times before the tests were stopped due to broken graphite blocks. As a result of these experiments, engineers assigned to the project concluded: "There was definitely nothing revealed in any of these tests which indicated that the blocks would not perform their desired function until 1985."[83]

Among other projects practiced and performed by DUN-UNI on the N-Reactor models in the 189-190-D Building throughout 1972-1975 were replacements of many varied gaskets and valves, process tube flow monitoring tubing, development testing of RTD spray shields, confirmation testing of strap-on RTD connectors, thermal hydraulics studies necessary for the conversion of the reactor's shield cooling system to a re-circulating mode, measurement devices and procedures to determine the thickness of process tube connectors, and development of the Technical Specifications (safety standards that replaced the older Hanford Process Specifications) for boiling point suppression equipment capable of providing low pressure protection. Additionally, freezing as a technique to block the flow to block valves in the rupture monitor rooms, developmental testing of prototype equipment to measure process tube elongation and elongation forces, work to determine procedures for establishing once-through coolant flow during major reactor component maintenance, trials of V-12 valve vibrator installation techniques, and flow testing of Mark IA fuel were carried out in the NPR-Prototype Concept Evaluation Loop in the 185/189-D facility.[84]

During the same years, BNWL executed many flow and thermal hydraulics trials in connection with developmental contracts for various power reactors. It analyzed the effects of uniform core blockage on pressurized water reactor core flow during reflood following a postulated loss-of-coolant-accident, the core flow distribution during the downflow period during a loss-of-coolant-accident, reviewed the effects of housing wall temperature on heat transfer results, examined the thermal hydraulics of a new, fusion-fission hybrid, gas-cooled reactor concept, studied flow and pressure in rod bundle subchannels containing blockages, and evaluated "dry" versus "wet" cooling tower heat removal systems

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83 Lander, UNI-122; and Lander, UNI-122 Add. A, p. 1.

84 Pociluyko, DUN-7432-D; and Flickinger, DUN-6576 Add 1; and Shoemaker, DUN-7073 Sup 2; and Lattin, UNI-164; and Lattin, UNI-214; and Etheridge, UNI-139; and Cummings, UNI-245; and Kratzer, UNI-70-E.2.a; and Bartlett, UNI-274; and Lander, DUN-8054; and Lander, DUN-8119; and Simsen, UNI-23; and Weed, UNI-438; and Pociluyko, UNI-466; and Pociluyko, DUN-8157; and Russell, UNI-104; and Pociluyko, UNI-81; and Eirich, UNI-464; and Weed, UNI-373 B; and Shaw, UNI-279; and Fields and Worley, UNI-501.

for pressurized reactors.[85] In 1972, the HTLTR lost its funding to the FFTF program and closed. The final FFTF support experiment using NaK was carried out in the 185/189-D Building in early 1972. Thereafter, this work moved to the new 337 High Temperature Sodium Test Facility.[86]

Throughout 1976-1979, the experiments conducted in the 185/189-D Building by the two contractors, UNI and BNWL, remained typical of the few preceding years. UNI carried out work in support of N-Reactor operations, while BNWL (which officially became the Pacific Northwest Laboratories - PNL -in 1977) did limited N-Reactor support work and a variety of experiments for offsite power reactors. Among the projects examined by UNI were a backup fuel cladding failure monitor, new flow-temperature data logger equipment, the effects of "upsetting" on the physical and flow properties of Zircaloy-2 pressure tubes, much valve simulation and testing work, reliability upgrading of the fog spray system, seismic and reliability upgrading of the confinement filter spray system, process tube drag measurements, and the use of new ultrasonic flow meters. Thermal tests of new graphite boron carbide safety shutdown balls proposed for N-Reactor were conducted in a furnace and a compression machine located in the 185/189-D facility.[87]

BNWL developed computer programs to analyze the thermal hydraulic characteristics of rod bundle nuclear fuel elements and cores, and then compared the program results to actual laboratory results achieved in test equipment in the 185/189-D Building. Among other programs, it also conducted experiments to evaluate the effects of sleeve blockages on axial velocity and intensity of turbulence in unheated rod bundles, it investigated and summarized several concepts in "dry" and "wet" heat removal systems for pressurized reactors, established a set of preliminary requirements for a helium-cooled blanket heat removal system for fusion reactors, began using laser Doppler anemometer techniques in taking fluid flow measurements in rod bundles, developed a nuclear fuel pin simulator for testing loss-of-coolant-accident related studies of Zircaloy-2 oxidation, and studied the single-phase flow fields around

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[85] Sutey and Rowe, BNWL-B-187; and Sutey and Rowe, BNWL-B-188; and Sutey and Rowe, BNWL-B-189; and Sutey and Stewart, BNWL-B-283; and Wolkenhauer, Leonard, Sutey and Moir, BNWL-SA-4865; and Rowe, Wheeler and Fitzsimmons, BNWL-1771; and Zaloudek and Johnson, BNWL-1878.

[86] Collingham, Yatabe, Hill and Thorne, HEDL-TME-72-23; and Asay, HEDL-MG-17, Rev. 6, pp. 65-72.

[87] Erickson, UNI-565; and Erickson, Arnold and McCullough, UNI-617; and Alexander, UNI-881; and Alexander, UNI-894; and Trimble, UNI-874; and Weed and Etheridge, UNI-462; and Shoemaker and Etheridge, UNI-906 RD1 Add 2; and Takasumi, UNI-725 Rev 2; and Eirich, UNI-939; and Wittekind and Toffer, UNI-1318; and Pociluyko, UNI-1331.

Note: Upsetting was a method of restoring elongated pressure tubes to their original length via heating and shortening.

steam generator tube support plates in pressurized water reactors.[88] BNWL also carried out a limited number of experiments in support of N-Reactor operations, including boiling burnout studies of the conditions in the inner annulus of Mark IV fuel elements fitted with various types of spring supports.[89]

SIMULATIONS IN 185/189-D AID IN N-REACTOR REPAIRS IN 1980'S

As the N-Reactor approached and arrived at 20 years old in the early 1980s, it began to experience system failures of many types. During these years, UNI work in the 185/189-D facility served a vital function in building and testing mockups and procedures needed to facilitate repairs to the reactor. During this period, the 185/189-D laboratory was operated by the Systems and Equipment Development Section of UNI. Its mission was to "develop new systems and components not available on the current market to support the programmatic functions of the 100-N Reactor...define detailed performance criteria for complex mechanical and instrument systems and components...test new components for compliance with performance criteria and specifications...conduct advanced systems studies and development... provide training simulations design, development and operation...perform on-reactor and supporting facilities equipment failure analyses..." and many other related tasks. The 185/189-D operating section also performed instrument calibrations and reviewed computer applications to simulations and development projects. Examples of "special processes instructions" included the development of procedures for N-Reactor tube shortening and safety ball channel repair.[90]

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88 Wheeler, Stewart, Cena, Rowe and Sutey, BNWL-1962; and Creer, Rowe, Bates, and Sutey, BNWL-1965; and Creer, Rowe, Bates and Sutey, BNWL-SA-6207; and Johnson, Allemann, Faletti, Fryer, and Zaloudek, BNWL-2120; and Zaloudek, Allemann, Faletti, Johnson, Parry, Smith, Tokarz and Walter, BNWL-2122; and Johnson, Zaloudek, Fricke, Helenbrook and Bartz, BN-SA-1064; and Sutey, Zaloudek, and Bomelburg, BNWL-2301; and Stewart, Bampton, Aase and Sutey, PNL-2477; and Kreid, Creer, Bates, Quigley and Sutey, PNL-SA-7772; and Fitzsimmons, McKinnon and Sutey, BN-SA-787; and Bates, Stewart and Sutey, BN-SA-1017.
Note: Laser Doppler anemometry (LDA) was/is a method of studying the flow of particles and fluids. It employed the Doppler effect (wherein the frequency of a moving light or sound source appears to change when it passes a stationary observer). LDA made use of the Doppler shift in light scattered by particles passing through a stationary laser (an improvement over older, streak and strobe photography techniques) to measure the particle velocity and, by inference, the velocity of the fluid in which the particles were suspended. Unlike many techniques based on probes, LDA did not disturb the flow being measured. The LDA measurement device used in the 185/189-D experiments recorded changes in light frequency from a reference beam, relative to beams generated by particles suspended in fluid (coolant water) as they passed rapidly through rod bundles at varying temperatures.

89 McSweeney, Thorne, Fitzsimmons and Anderson, BNWL-CC-1811.

90 Erickson, UNI-1437, Rev. 2, pp. 5-6, 10, V-1.

One fundamental problem that accompanied the aging of N-Reactor was that of swelling and distortion of the graphite stack (core). The graphite stack was an assembled unit of blocks, with tube blocks oriented front to rear and filler blocks oriented side to side between each tube block layer. The blocks were keyed together except at slip joints provided across the center of each layer. Under prolonged irradiation, the N-Reactor graphite by the early 1980s had contracted linearly in the parallel direction (along block length) but had contracted more slowly and eventually had expanded in the transverse direction (block thickness direction). The slip joints could not accommodate all of the local distortion, and some block cleavage had occurred, along with actual separation of blocks within central sectors of the stack. Such changes in the stack had produced distortions in the horizontal process, cooling and safety rod tubes that were most severe in the side fringes, even causing "significant charging problems" by 1982. Vertical tube distortion occurred, especially in the center of the reactor where transverse contraction had resulted in a total sag of about three inches. Additionally, tubes became elongated under the stress of irradiation, and many "minimal" connector clearances were found during the 1982 summer outage.[91]

During the early 1980's, a complete mockup of portions of the N-Reactor stack, complete with current graphite misalignments and with horizontal and vertical tubes exactly duplicating the curvature caused by the misalignment, was re-constructed in the 185/189-D Building. During 1984-1985, procedures were developed in the facility for HCR channel distortion and blockage testing, and standards were validated for the testing of new tube materials. In 1986-1987, a special process tube removal jack, with an expanding mandrel adapted to the bent and blocked tubes and channels, was developed and tried, as was new equipment for profiling the curvature of the HCR channels and for characterizing the inside thicknesses of various points along deformed tubes.[92]

Also within the 185/189-D Building was the N Reactor Loop Component Test Facility, a high temperature, pressurized, recirculating demineralized water test loop. It also had the capability to run single-pass dump tests. It consisted of a 55 horse power (HP) liner motor centrifugal pump, a 200 HP four-stage special high pressure pump, two single-pass counter flow heat exchangers (each designed to remove 2,700,000 BTU per hour), a 300 KW immersion line heater, main loop piping fabricated of four-inch Schedule 160 seamless carbon steel, the make-up water system, the clean-up water and sampling system, a pressurizer, and control and monitoring instrumentation. The make-up water system was composed of a demineralizer, 650-gallon demineralized water storage tank, rapid-fill centrifugal pump, a high pressure injection pump and a chemical feed tank. The clean-up and sampling water system was composed of a restricting

[91] Scott, UNI-1960, pp. 1-3, 13-17; and Newby and Marshall, UNI-2109; and Lyon, UNI-2110.

[92] Nelson, UNI-3329; and Nelson, UNI-3422; and Zaloudek and Ruff, UNI-3653 (PNL-5924); and Zaloudek and Ruff, UNI-3994 (PNL-5930); and Lee, UNI-4193; and Nelson, UNI-4191 Rev. 1; and Alzheimer and Gonzalez, UNI-4285; and Martek, UNI-4263.

orifice to limit flow, a heat exchanger to cool the process water, filters and a flow indicator.[93]

Within the N-Reactor Loop Components Test Facility, other reactor difficulties were modeled and/or evaluated, including characterization of leaks in the primary flush lines of the emergency core cooling system, flow tests involving the partial operation or shutdown of various valves, replacement plans and procedures for these valves, investigations of the thermal hydraulic bases for operating the reactor when only four of its five cells were operating (due to the closure of Cell Number Five for steam generator replacement in 1982), repair criteria for the fuel rupture monitor sample water reinjection system, and examination of the process tube flow monitor system. Additionally, a safety study was conducted of the boiling point suppression and high temperature emergency cooling system instrumentation and of other reactor surveillance equipment.

Another mockup was built to test inspection and removal equipment for the graphite cooling tubes and to cut and dispose of the graphite incore fission chamber assemblies. Acceptance test procedures were developed for a new process tube drying system in early 1987, at nearly the same time as leak and flow characteristics of the reactor's V-11 valves were evaluated against a newer design. Other trials examined the thermal fatigue of N-Reactor fuel closures, the flow resistance of various process lines, the ultrasonic detection of various leaks, the thermal gradients in various states of standby, the flush characteristics of different spacers, and many other issues.[94]

During the same years, BNWL work declined in the 185/189-D Building, as there were no new orders placed by power companies for nuclear reactors during the decade. During the 1980s, some work was done in thermal modeling and simulation tests for the Department of Energy (DOE - modern federal management agency overseeing the Hanford Site and other nuclear defense sites) Seasonal Thermal Energy Storage program, in simulated fuel rod tests of pellet-cladding interaction in light water reactors, and in drop tower compression trials.[95] The last project done in the 185/189-D Laboratory was a UNI endeavor to build an indoor electrical substation in the facility, complete with a transformer, circuit breaker and incoming and outgoing sections. The project was completed in 1987. However, in February 1988, the DOE announced that N-Reactor, closed

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93 Pociluyko, UNI-M-87, pp. 3-8.

94 Lyon, UNI-1986; and Cummings, UNI-2063; and Rainey, UNI-2182; and Conn, UNI-2227 Rev. 1; and DeMaria, UNI-3481 Rev. 1; and Shoemaker and Fuller, UNI-2016; and Reeves, UNI-610 Rev. 1; and Lechelt, UNI-2925; and Lattin, UNI-3333; and Rasmussen, UNI-3583; and Stauch, UNI-4210; and Linschooten, UNI-4148; and Pope, UNI-4239; and Smith, UNI-4253; and Sullivan, UNI-4225.

95 Kannberg, PNL-4281 Vols. I and II; and Barner, Fitzsimmons, Lanning and Williford, PNL-SA-11651; and Barner and Fitzsimmons, PNL-5245 (NUREG/CR-3999); and Dudder, PNL-SA-12040.

for repairs since January 1987, would not re-start. Lacking work, the 185/189-D Building closed later in 1988.[96]

190-D AND 190-DA BUILDINGS

CONSTRUCTION AND USAGE

The 190-D Process Pump House was constructed at HEW by the DuPont Corporation during 1943-1944. It was completed in the autumn of 1944, just in time to conduct acceptance testing for the startup of D-Reactor on December 17, 1944. The 190-D facility was large (456 feet long by 187 feet wide by 67 feet high), and contained 14 steam-powered and 14 electric-powered water pumps, four neoprene-lined,[97] storage tanks (clearwells) capable of holding 1,750,000 gallons of treated reactor process water each, as well as motors, air compressors and other ancillary equipment.[98] The original purpose of the 190-D Building was to store and deliver 30,000 gpm cooling water to D-Reactor via twelve 12-inch pipes, located in an underground tunnel, to a common header in the valve pit at the front side of the pile. From that point, other pipes split the water flow and carried it through the reactor. In the 190-D Building, the corrosion inhibitor sodium dichromate, deemed important by CMX experiments in preserving reactor process tubes, also was added to the process water.[99]

The principal function of the 190-D Process Pump House never changed through all the years of D-Reactor operations (1944-1967). However, after the construction of the 190-DA (Annex) Building in 1956, the pumps in the 190-D Building became the backup or secondary coolant supply pumps, while the newer pumps in the 190-DA Building became the primary pumps. Additionally, with the construction of DR (D Replacement) Reactor in the 100-D Area in 1948-49, an extension was built on to the south end of the 190-D Building to supply cooling water from that facility to the DR-Reactor. However, in the midst of this construction period, further studies in the thermal annealing of graphite demonstrated the strong possibility that expansions and distortions of the D-Reactor graphite could be ameliorated. In the spring of 1949, it was determined that a reasonable operating lifetime could be anticipated for D-Reactor, and therefore that a separate 190-DR Process Pump House should be built.[100]

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96 Walker, UNI-4214 Rev. 1; and Sivula and Whitney, "Cold Standby...", February 17, 1988.

97 Neoprene is a registered trademark of the DuPont Corporation of Wilmington, Delaware.

98 DuPont, HAN-10970, Book III, pp. 749-751; and Trumble, HW-44708 Vol. II, p. 30. Note: The most authentic physical descriptions of the 190-D Process Pump House can be found in DuPont, HAN-10970, pp. 749-75, and in Gerber, WHC-MR-0425, pp. 9-10.

99 DuPont, HAN-73214, Book 11, pp. 73-76; and Kidder, HW-7-4444.

100 G.E. Hanford Company, HW-24800-7, pp. 5-6; and G.E. Hanford Co., HW-22201-DEL, pp. 28-29; and Woods, HW-10972, p. 11; and Lewis, HW-11262; and Pile Engineering, HW-11829, p. 9; and Reinker and Johnson, HW-15295, p. 9; and Botsford,

During 1955-1956, the 190-DA Building was constructed as part of Project CG-558, Reactor Plant Modifications for Increased Production. The purpose of this structure was to house larger pumps and motors capable of supplying more coolant to D-Reactor. The expansion was undertaken because Hanford Works studies had determined that the older reactors were "currently incapable of operating at their maximum potential power levels because of a limited availability of process cooling water." The 190-DA Building was designed to supply 74,000 gpm process water, 3,500 gpm non-process water (for fire-fighting and other needs), 10,000 gpm "export water" (water supplied to the 200 Areas) jointly with the 190-DR Building, and 2,000 gpm miscellaneous water jointly with the 190-DR Building. Eight, 450-HP, electrically driven pumps capable of delivering 10,500 gpm each were installed in the 190-DA Building. Seven of these new pumps were designed to provide the necessary, ongoing supply and the eighth one was planned as the spare. The old, steam-driven pumps in the 190-D Building were retained for emergency and shutdown use, while the original electric-driven pumps became the suppliers of secondary backup coolant water to D-Reactor. The twelve 12-inch lines leading to the valve pit of the pile were augmented with two 18-inch carbon steel pipes. New risers, crossheaders, pigtail connectors, and nozzles also were installed at the front face of the reactor to improve hydraulic efficiency.[101]

During 1959-1960, further studies were undertaken at Hanford Works into methods of expanding the pumping capacities of the 190-D and 190-DA Buildings. With process water flow rates then standing at 80,000 gpm, there was a desire to know whether rates as high as 85,000-95,000 could be achieved. Numerous scenarios and possible modifications were examined. The decision that was made involved replacements and additions to the reactor's front crossheaders and crossheader fittings, front nozzle assemblies and gunbarrels. These changes lessened the pressure drop from the pumps to and through the reactor process tubes, thus increasing coolant flow without modifying the pumps, motors, flywheels and other equipment in the 190-D and 190-DA Buildings.[102] On June 26, 1967, D-Reactor was deactivated and the 190-D and 190-DA equipment and facilities ceased operations. The pumps, motors and other devices were removed to other reactor areas and/or excessed within the next two years. There were no future missions for either of these buildings except that of storage for some of the experimental components used in the 185/189-D facilities.

Reinker and Johnson, HW-17373, p. 6; and Hanford Works, HW-17679, p. 3; and Reinker, Botsford and Lewis, HW-18163, p. 14.
Note: There were/are <u>many</u> other sources concerning the thermal annealing of graphite, and the 1948-1949 experiments in this field at D-Reactor. This is not the primary topic of this report, and therefore only a partial list is supplied.

101 Russ, HW-30401 Vol. I, pp. 6, 8; and Trumble, HW-44708 Vol. 2, pp. 30-33.

102 Quackenbush, HW-62813; and Heacock, HW-60596; and Fifer and Kempf, HW-63351, p. 9; and Bauer, Harrison, Hill, McLenegan and Mondt, HW-63487, pp. 8-16.

195-D VERTICAL SAFETY ROD TEST TOWER

CONSTRUCTION AND USAGE

The 195-D Vertical Safety Rod Test Tower was constructed in 1957 in order to conduct safety-related testing of the VSRs of the eight then-existing Hanford reactors. The facility was tall and narrow (18 feet square by 120 feet high), and originally contained simulations of the VSR channels, mechanisms and equipment of the single-pass piles.[103] Its construction coincided with major upgrades and expansions of the pumping and piping systems of the Hanford reactors, in order to allow increased power levels. At the time that these increases were proposed, the AEC and the HW operating contractor G.E. Hanford Company began intensive review of all of the safety and control equipment associated with these reactors. In 1955, the AEC specifically requested "a review of the mechanism and operation of the K Reactor safety rods...This review should include time of travel, position indication, whether releasable during rise, consequences of mechanism failure, etc."[104] The contractor proposed that, in conjunction with the reactor plant modifications for increased production, "installation of improved, faster acting vertical safety rods is planned. This...can be justified on the basis of improved pile safety. New rods would be required for B, C, D, DR, F and H Piles, [and] a slight modification of the K Pile rods is necessary." The total budgeted cost for the VSR improvements was over $4.5-million.[105] To accommodate the needed developmental and testing work, the 195-D Building was constructed.

By 1957, mechanical design was underway for Project CG-708, "Additional VSRs, KE and KW Reactors," and Project CG-709, "Improved VSRs, All Areas," had been approved by the AEC. The most salient areas needing improvement was the speed of insertion, with rod insertion time defined as the "interval between first movement and 90 per cent downward travel of the rod."[106] The new rods were air-driven in order to increase their speed of insertion, and they were first tested in the 195-D facility. By 1960, they had been installed in the reactors, and were being cited in safety reviews presented to the AEC as enhancing the safety margin for increased reactor power levels. By 1962, Hanford Technical Specifications required that rod insertion occur in 2.4 seconds at the older reactors and in 2.3 seconds at the KE and KW Reactors.[107]

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103 AEC/GE Study Group, GEH-26434, p. 1.51.
Note: the most accurate descriptions of the 195-D Building can be found in the above reference and in Hanford Site Drawings H-1-5695, H-1-5696, H-1-5697, H-1-5698, H-1-13140, H-1-36743 (sheets 1 and 2), H-1-36744 (sheets 1, 2 and 3), and H-1-39439.

104 Greager, HW-36621, p. 7.

105 Greager, HW-36920, p. 7.

106 IPD Personnel, HW-49826, pp. D-5-6; and Gilbert, HW-71619 RD Rev. 4, p. 6.

107 Trumble, HW-61580, p. 11; and Trumble, HW-64894, p. 18; and Gilbert, HW-71619 RD.

During the same years that the dramatic power level increases were taking place in the Hanford reactors, the reliability of the Ball 3X systems also came under scrutiny. The Ball 3X systems were first installed on the five oldest piles during the major upgrades of the mid-1950s. Almost Immediately, according to the contractor, several inadvertent ball drops occurred, "many of which required considerable recovery time...Because of this, interest has been expressed by reactor operations personnel toward provision of a ball recovery system which would substantially reduce these outages." Prototypical in-pile ball removal equipment was designed and then tested in the 195-D Tower. In 1959, the AEC recommended that "further consideration be given to the possibility of jamming the [3X] balls in the safety system with or without the rods present, because of the small clearances involved." Due to this concern, tests continued.[108]

By the late 1960s, N-Reactor also was experiencing multiple problems with its Ball 3X system. A 1969 engineering study stated: "During past ball recovery operations, a number of components have routinely failed to function as designed, causing unnecessary plant outage consumption and unnecessary personnel radiation exposure...It is apparent that a number of modifications and additions are required to achieve the desired level of operation." Components needing attention within the ball system itself included the screw conveyors, the glass switches, capacitance level probes, inspection facilities and equipment, metering hoppers, hopper fill hoses, sorting valves, ball exit drain valves, ball washer system, dryer exhaust fan filter, skip hoist and bucket, and communications devices between the ball control room and the top of the unit.[109] Additionally, graphite blocks In the reactor stack had migrated into some of the ball channels.[110]

Throughout the following 15 years of N Reactor operations, tests were conducted in the 195-D Building to evaluate various aspects of ball mechanics and operation, and of the issues and difficulties raised by graphite distortion effects on the ball channels. These trials included examinations of the ball channel funnels, alternate ball sizes and compositions, alternate types of channel sleeves, the reliability of restricter orifices in the channels, the development of inspection and repair procedures for a major ball system renovation project planned in 1982, and the establishment of criteria for the ball system upgrade that actually occurred in 1984.[111] Following these early and mid-1980s repairs, very little work was done in the 195-D Tower. The facility closed with the closure of N Reactor in 1987-1988.

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108 Walker, HW-50351-DEL, pp. 2-8; and Greager, HW-36621, p. 3.

109 Adachi, DUN-6333, p. 1, 2-14.

110 Cooperstein and Newby, DUN-6503.

111 Russell, DUN-8122; and Pursley, UNI-163; and Newby, UNI-70 A11; and Cook, UNI-374; and Russell and Hole, UNI-779; and Toffer, UNI-1322; and Roach, UNI-2027; and Hanson, UNI-2004; and Ruane, UNI-2206 Rev. 1.

1724-D BUILDING

CONSTRUCTION AND USAGE

The 1724-D Underwater Test Facility (also known as the Fuel Discharge Test Facility) was constructed in 1973 in order to conduct trials directed at improving the discharge procedures at N-Reactor at the Hanford Site. The facility contained 2,316 square feet of space including a 20-foot deep water pool designed to simulate the irradiated fuel storage basin at N-Reactor, and a jib crane for manipulating test equipment. A 600-square foot addition was added to the facility at an unknown date.[112]

The original and continuing purpose of the 1724-D Building was to examine and develop solutions for two problems that were plaguing N-Reactor. In the first reactor discharge operations, a soft aluminum "tip-off" with an offset chute had been attached to the outlet nozzles on process tubes. The tip-offs were meant to allow the irradiated fuel to clear all piping on the discharge face as it fell into the Irradiated fuel storage basin. However, the equipment developed problems because a locating-locking finger behind the connector made them hard to install and remove, and, more importantly, because fuel sometimes stuck in them. The second problem concerned the "trampolines" (metallic sloping nets or mats) submerged in the irradiated fuel basin. These devices were meant to "break the fall" of irradiated fuel elements as they were discharged into the basin. (In other words, the trampolines were intended to cause the fuel elements to give up the kinetic energy from their fall in a gentle way.) Without the trampolines, the high velocity attained by the discharging fuel (especially that from the top rows of the 33.3-foot high reactor stack) sometimes caused the fuel cladding to rupture In the basin. Both of these discharge-related problems came under study during the 1970s and 1980s as part of fuel element handling enhancement programs at N-Reactor.[113]

Among the specific issues examined in the 1724-D Building were new spring-loaded designs for the anchors that attached the chain mat (trampoline) to the side basin walls, new tip-off designs and installation procedures (including a flow-blockage tip-off), anti-flush devices (spring-loaded hooks) that would drop in front of the open rear process tube caps during discharge operations, and design criteria for a new automatic refueling system being developed in 1986.[114] The 1724-D facility ceased operations with the closure of N-Reactor in 1987-1988.

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[112] Physical descriptions of the galvanized steel 1724-D facility are elusive. The most accurate description can be found in Hanford Site Drawing H-1-45922.

[113] Lander, UNI-77; and Leitz, UNI-2081; and Anderson, UNI-2178.

[114] Hanson and Roach, UNI-2086; and Eyre, UNI-2326; and Eyre, UNI-2326 A; and Morrison, UNI-2326 B; and Strickler, UNI-2326 C; and Strickler and Eyre, UNI-2326 D; and Warner, UNI-2326 E; and Strickler, UNI-4151; and Nelson, UNI-3440; and Magnus, UNI-3410 Rev. 1.

Physical Description

Deaeration Plant (185-D)

The 185-D building was 306 feet long by 48 feet wide and 182 feet high, situated adjacent and east of the 189 Building. The height differential compared to the "smaller" 189 Building was due to the prescence of ten, 4-stage, rubber-lined deaeration units ("towers") mounted vertically on steel structures on top of the 185-D building. "185-D also contained 20 acid dilution tank pumps, 18 other pumps, 16 storage chemical tanks, a proportioner feed tank, and a one/half ton transfer monorail and hoist" (Gerber 1994: 1). The deaerators (towers), acid feed tanks, pumps, transfer monorails and hoists and an instrument room assisted in the water filtration process.

The ten, 4-stage, rubber-lined deaeration units were mounted vertically on steel structures above the building near 190-D. The units extended from a height of 100 feet to 174 feet above the building floor elevation. The piping extended down through the roof of the main structure into the adjacent 190-D building, and also into the 189-D building.

Experiments with the deaeration towers found "film formation on simulated reactor process tubes to be a serious problem, but they also found no difference with or without the use of deaerated water...Thus, the huge deaeration equipment installed in the 185-D building was never used" (Gerber 1994: 2).

Since the deaeration equipment in 185-D never served its original purpose, the equipment was removed (in the early 1950's), part of the common wall with the adjacent 189-D building was demolished, "and a new corrosion, heat transfer and 'thermal hydraulics laboratory' was emplaced in the now-joint structure (185/189-D) ... conversion and modifications within 185/189-D began in 1951 ... Equipment included 60 short process tube mock-ups, several sets of hydraulic heads for these tubes, a 50 kilowatt (KW) electrical induction heating coil, a weighted tube corrosion apparatus, 'dummy' fuel elements, a 25-ton crane capable of traversing the entire length of the 189-D building, and stacked graphite blocks to simulate varying deflection slopes for process tube entry" (Gerber 1994: 4-5).

Existing Conditions

Built in 1944, 185-D consists of one main structure with a reinforced concrete foundation, concrete block superstructure, steel framing and trusses, and a precast concrete roof slab with a built-up roof consisting of a tar and gravel surface. The building is entirely above ground level except for a reinforced concrete underground pipe tunnel and reinforced concrete acid trench which runs the entire length of the building.

The long axis of the building runs in a north-south direction. The east wall of 185-D forms part of the adjacent wall of 190-D, while the west wall of 185-D forms part of the adjacent wall of 189-D. 185-D and 189-D are now considered one building, together measuring 307 feet long by 55 feet wide by 53 feet high, Recently one-third of the facility was used as a mechanical development laboratory with flow and graphite lattice mock-ups. Another third was occupied by Hanford's thermal hydraulics laboratory, and the remainder housed extensive service and craft shop facilities and a storing area.

Subsequently, all of the 185 buildings at Hanford were modified and used for various process laboratory development activities, including equipment mock-ups.

Little significant equipment and machinery remains in 185-D from the Manhattan Project and Cold War eras. Only the interior piping, girders, posts, stairwells, the mezzanine, and the basic fixtures of the thermal hydraulics laboratory are extant. Office, rest room and lunch room additions are also intact.

Refrigeration Building (189-D)

The 189-D facility was 307 feet long by 76 feet wide by 53 high, and contained six industrial refrigeration units, six evaporative coolers, seven pumps, as well as lifts, hoists and freon tanks.

189-D functioned as part of the influent water cooling system for the D-Reactor, delivering chilled water to the central process tubes of D-Reactor. Cooling water first was pumped from the Columbia River at the 181-D pump house, purified and treated in the 182-D reservoir and pump house (and in the 183-D filter building), deaerated in the 185-D plant, and then cooled in 189-D. (The process water flowed from the 185 building into the refrigeration room of the 189 building where it was chilled and pumped into either or both of the two center storage tanks in the 190 building.) Water then flowed into the 190-D process pump house, and was delivered to the front risers of the reactor building itself.

While the purpose of the189 building was to cool the process water before it went through D-Reactor, thus, allowing the reactor to operate at a higher power level and still not heat the process water to the point where it would flash to steam, it was soon discovered that it was not a necessary step in reactor operations. Thus, the building never served its original purpose, and was soon outfitted for other uses. (The original pedestal foundations and well pits were removed and filled.)

The 189-D building originally consisted of a large refrigeration room, an electric control room, a Freon tank pit, and two ventilating rooms. Along one side of the refrigeration room, and adjacent to the common wall between 189-D and 185-D, were two concrete pipe trenches covered with steel grating at floor level. The facility contained six industrial York refrigeration units (with a total capacity of

14,000 tons of refrigeration), six evaporative coolers, seven pumps, as well as lifts, hoists and freon tanks.

In the center of the refrigeration room was a reinforced concrete Freon storage tank pit extending some 13 feet below floor level. Adjacent to the pit at floor level were six chilled water pumps which maintained the proper water pressure throughout the system. Along the wall opposite the 185 building were two ventilating rooms which housed the evaporator cooling units. Along this wall and adjacent to the south ventilating room was the electric control room which housed the electric switchgear and motor generator sets used in the operation of the building.

Later, a Flow Laboratory (thermal hydraulics and coolant systems development studies laboratory) was established in part of the structure, whose purpose was for heat transfer and fuel corrosion studies. The laboratory consisted of a system of pipes and tubes that could be loaded with dummy fuel elements. These elements were then heated electrically while water passed over them in pipes, so that heat transfer from film build-up could be studied.

Existing Conditions

Measuring 301 feet by 76 feet wide and 53 high, 189-D has a one-story, concrete block superstructure, a reinforced concrete foundation, steel framing and trusses, and a precast concrete slab roof covered by a built up roof of tar and gravel. The long axis of the building is north-south, parallel to and a common wall with the 185-D building. 185-D and 189-D eventually merged into a single facility due to common functions and features: one-third was used as a mechanical development laboratory with flow mock-ups, another third was occupied by Hanford's thermal hydraulics laboratory, and the remainder housed extensive service and craft shops. The facilities were used for boiling burnout, fog cooling, transient heat transfer, and flow instability studies.

The most significant machinery/equipment that remain are from the thermal hydraulics laboratory and from other research and development (R & D) activities. Extant machinery includes "Charge/Discharge" testing equipment, a machine shop for R & D testing, and "Temperature and Flow Control Panel Boards". The panel boards are General Electric 150 KW preheater controller "switchboards" that were used with two adjacent 2300 volt "D. C. Turbine Generators".

Tank Room and Process Pump House (190-D)

Built in 1944, 190-D provided coolant water for D-Reactor. The structure consisted of a large tank room (high bay) housing four process water storage tanks, a process pump room (low bay), a control room, an office, ventilating equipment rooms, electric switchgear rooms, battery room, air lock chambers, basement conduit room, two pipe tunnels, re-use pump room, and a water reservoir.

The 190-D building housed the next step in the reactor cooling water treatment process after the treatment and filtration steps that occurred in 183-D. Reactor process water was pumped to four 1,750,000 gallon steel storage tanks in the 190 pump house, where sodium dichromate was added to inhibit corrosion on the reactor's process tubes. Twelve sets of steam and electric pumps generated the ready water to the D-Reactor

The main section of the building, the high bay, housed the four large steel process water storage tanks capable of storing 7 million gallons of purified water and a number of electrically driven 10,000 gallon/min. pumps used for reactor cooling. Originally water flowed by gravity from deaerators in the adjacent 185 building to all four tanks in the 190-D building, while chilled water was pumped into the two center tanks from the 189 building. Parallel to the tank room was a smaller room running the entire length of the building and housing the twelve electrically-driven process water pumps in series with the twelve steam-driven process water pumps.

Existing Conditions

190-D is a one-story, concrete block superstructure with a "high and low bay", a concrete foundation, steel framing and trusses, and a pre-cast concrete roof covered with tar and gravel surfacing. The building is parallel and contiguous with 185/189-D, measuring 456 feet by 184 feet by 67 feet high, covering approximately 90,700 square feet.

At the south end of the "low bay" of 190-D the original control room (from the Manhattan Project period) is intact, although all significant equipment/machinery has been removed. The original tanks, bases and turbines throughout the facility have also been removed. The building's superstructure and steel frame (trusses, posts and girders) remain intact. Piping in the basement tunnels that connect the facility with 190-DA Annex and the D-Reactor are intact.

Due to safety concerns access to the "high bay" (tank room) was not allowed.

Process Water Pumphouse Annex (190DA)

Built in 1957, 190 DA served to expand the influent pumping and delivery capabilities for coolant flowing through D-Reactor. The main purpose was to deliver additional coolant water through the reactor, in order to maintain acceptably low temperatures while still raising the power levels of the reactor. It ceased operations in 1967 when D-Reactor was deactivitated. The pumps and other equipment were excessed within the next two years later.

Existing Conditions

The building is a one-story, reinforced concrete structure with a concrete foundation and floor, corrugated transite cladding over steel framing and trusses, and a pre-cast concrete roof covered with tar and gravel surfacing. The interior has insulated walls and ceiling. There is a 14 foot x 16 foot roll-up door on the east facade. The building's west wall is perpendicular and contiguous with the east wall of the 190-D building. The Annex measures 198 feet long x 86 feet wide x 40 feet high, covering approximately 16,000 square feet.

This building was later converted into a storage facility to meet the storage needs of 100-D development personnel and other contractors who lease the space for their programmatic storage needs.

The facility currently is housing a Pressure Tube Replacement Mock-up that was a vital piece of training equipment for N-Reactor operations before the reactor's closure.

VSR Test Tower (195-D)

Built in 1957, 195-D was used as an experimental laboratory to test the vertical safety rod (VSR) channels of the eight then-existing Hanford production reactors, at the time when rapid power level increases were taking place. Testing of new air-driven methods of speeding up VSR insertions were made. Originally fitted inside the facility was a VSR mock-up. Later, the Ball 3X ("last ditch") safety systems of all the Hanford reactors were tested in the facility. Equipment included a 3-foot diameter pipe surrounded by a 4-foot diameter graphite enclosure, 44 feet high, with a ball hopper and vacuum removal system.

Existing Conditions

The tower has a reinforced concrete foundation and floor, corrugated metal wall over steel framing, and a precast concrete roof built-up with tar and gravel surfacing. The structure is approximately 18 feet by 18 feet by 120 feet high (10 stories with a cable elevator), and covers approximately 324 square feet.

For safety reasons access to the interior was not allowed.

Underwater Test Facility (1724-DA)

In 1944, the current facility was an open concrete reservoir/holding tank for water that did not meet process specifications for use in the 190-D building. The enclosed superstructure was not completed until 1973. Also known as the Fuel Discharge Test Facility, the main purpose of 1724 DA was to conduct trials directed at improving the discharge procedures at N-Reactor, and test various slope angles and chain anchors of the trampolines, also in N-Reactor. The facility had a test trampoline and a 20-foot deep water pool to simulate the N-Reactor basin. (N-Reactor had a trampoline or metallic sloping net in its fuel storage basin, emplaced to gently break the fall of irradiated fuel rods. However, the velocity of their fall into the basin sometimes caused them to rupture.) The testing in 1724-DA involved simulated fuel pins dropped onto the trampoline, the results of which were used to optimize the fuel discharge trampoline design in the 105 N-Reactor.

Existing Conditions

This one-two story (split-level) structure measures 45 feet (E-W) by 40 feet (N-S) that covers approximately 2316 square feet, including a 600 square foot addition to the rear. The structure has corrugated metal cladding over steel framing, flat and shed roofs, a concrete foundation, a corrugated metal roll-up door, and interior metal flooring and railings. The 20-foot deep water pool designed to simulate the irradiated fuel storage basin at N-Reactor, a jib crane for manipulating equipment, and the trampoline, are still intact.

Project Information

Due to public health and safety concerns, the U. S. Department of Energy, Richland Operations Office (DOE-RL) is planning to demolish five structures located in the D-Reactor Complex at the Hanford Site, Washington; 185/189-D, 190-D, 190-DA, 195-D, and 1724-DA. The State Historic Preservation Officer (SHPO) concurred with DOE-RL's recommendation that one of the facilities, 185/189-D, is eligible for the National Register of Historic Places (Register) due to its significant role in nuclear reactor technology. While the remaining facilities individually are not considered to be eligible for the Register, collectively they have significance due to their structural proximity and common functional elements with the 185/189-D building. DOE-RL has concluded that the above undertaking will have an adverse effect upon the Register eligibility of 185/189-D.

Section 106 of the National Historic Preservation Act of 1966 (P.L. 86-665, as amended) requires all Federal agencies to take into account the effects of their undertakings on properties listed in or eligible for the National Register, and afford the Advisory Council on Historic Preservation an opportunity to comment on the proposed undertaking. As required by Section 106, DOE-RL entered into a consultation process with the SHPO and the Advisory Council to negotiate a Memorandum of Agreement (MOA) on means to avoid or mitigate the adverse effects of the proposed undertaking. The MOA required that DOE-RL mitigate the adverse effects by documenting the 190-D Complex to Historic American Engineering Record (HAER) standards. The stipulations in the MOA include a HAER narrative report, archival-quality photographic documentation of the properties, and photographic copies of original construction drawings.

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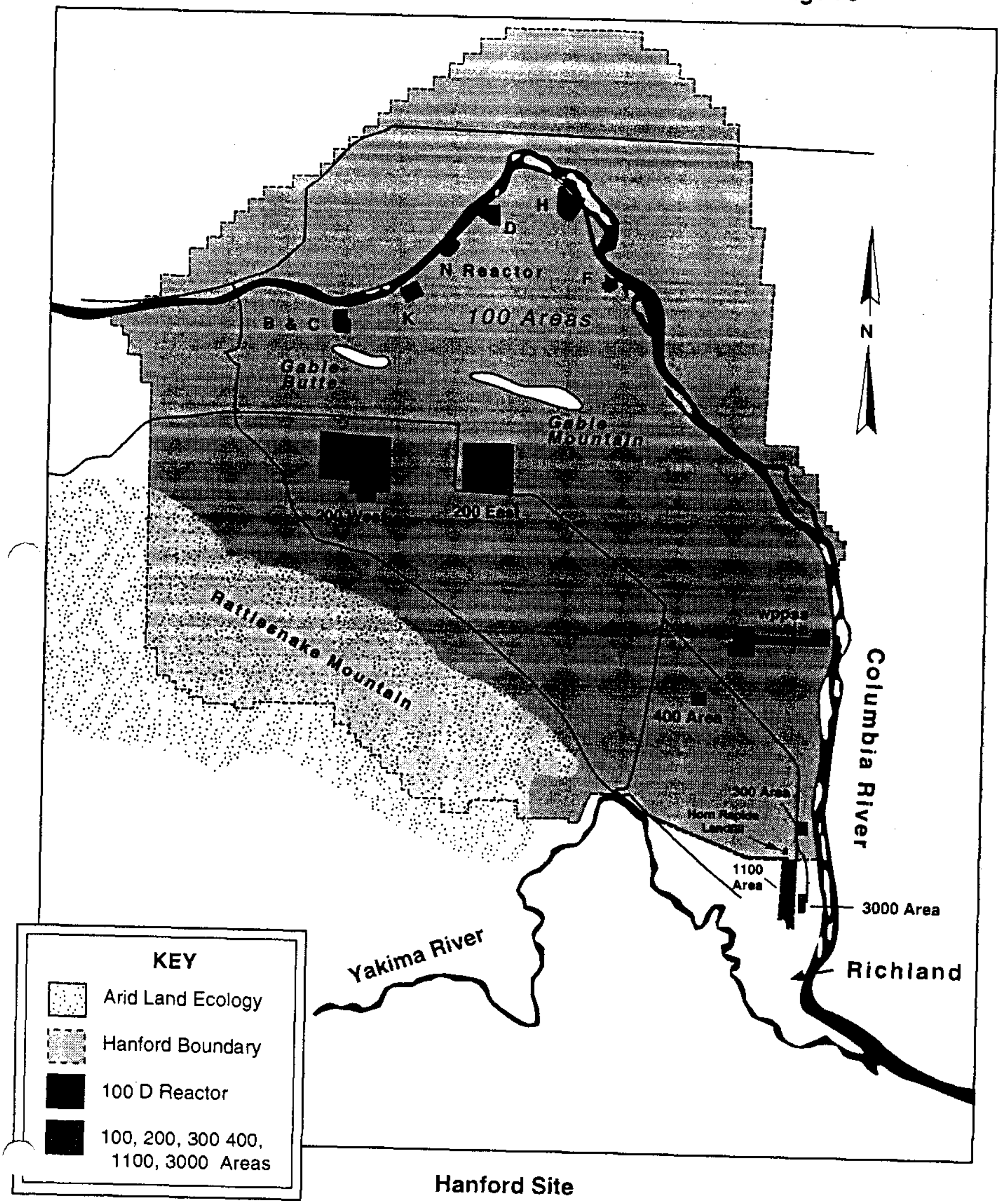
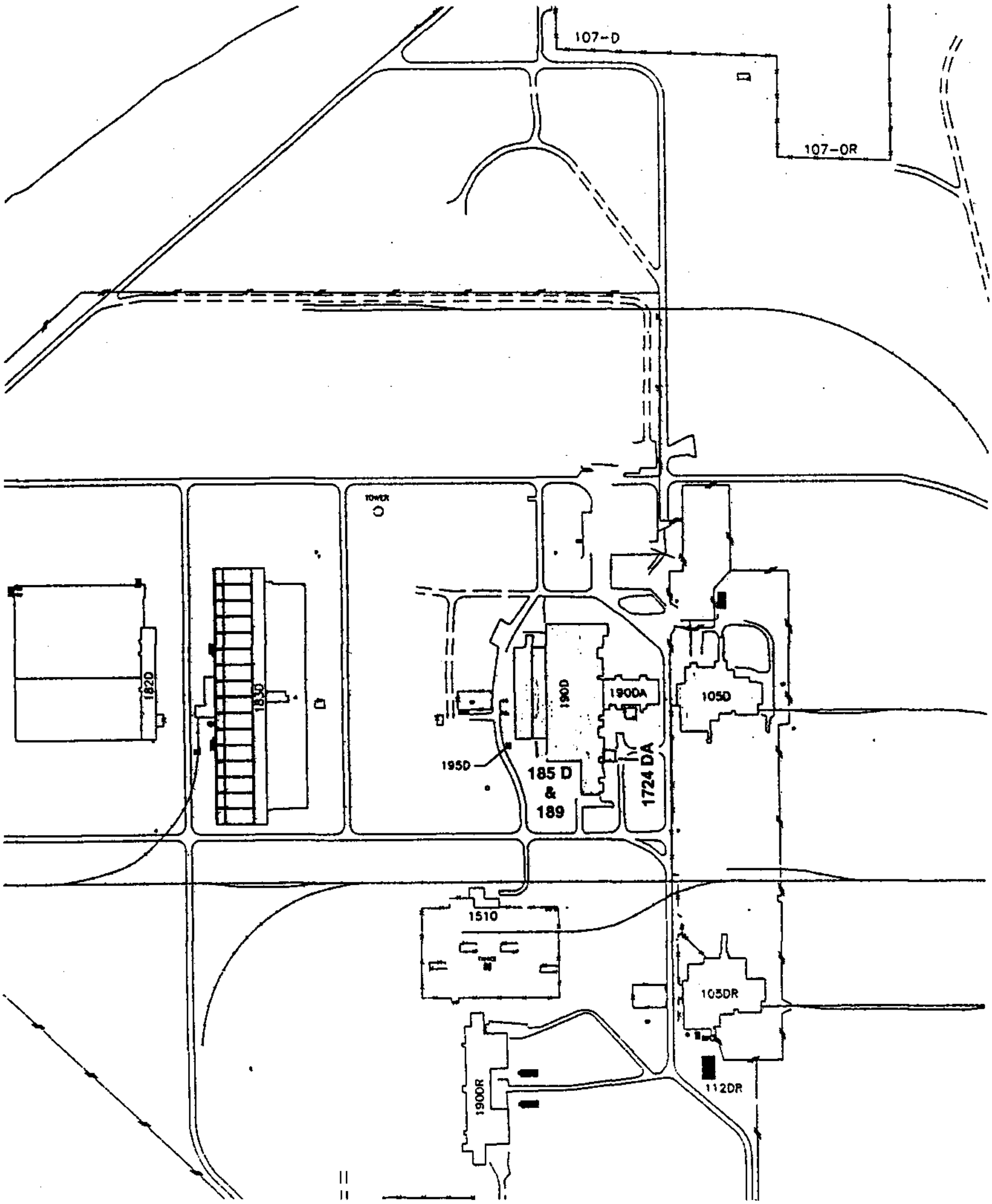


Hanford Site



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